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A TREATISE

ON

ROLL-TURNING

FOR THE

MANUFACTURE OF IRON.

By PETER TUNNER,

MEMBER OF AUSTRIAN MINISTRY OF MINES, ETC., ETC.

TRANSLATED AND ADAPTED

BY

JOHN B. PEARSE,

METALLURGIST, ENGINEER, AND MANAGER AT THE WORKS OF THE PENNSYLVANIA STEEL COMPANY.

ILLUSTRATED BY 34 WOOD-CUT ENGRAVINGS, TOGETHER WITH A FOLIO ATLAS OF LITHOGRAPHED PLATES.

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AUTHOR'S PREFACE.

THE use of rolls for the manufacture of iron is unquestionably an English invention. The first *grooved* rolls were constructed in the year 1783 by Henry Cort, who thereby laid the foundations of a magnificent industry, but suffered grievous ill-usage, and died a miserable death.

The subject of roll-turning has been so scantily treated in all the books which have described the manufacture of iron, that very little that is useful can be gleaned from their pages. None of the late books on the subject contain more information than was given by Karsten in 1841, though since that time extraordinary progress has been made in the art. The chief ground of this neglect of this vital branch of the industry is, in my opinion, to be found in the fact that those who have lately written on Iron Metallurgy have not, as a rule, been practical metallurgists, but only metallurgical chemists, and, therefore, they have neglected as trivial such things as passes, or, perhaps, have even held it beneath their dignity to write about them; they have, however, accomplished a great deal in their own branch.

Eduard Maürer published in 1865 a work, or rather atlas, containing the finished sections of many different kinds of iron; but there was nothing in his work which treated of roll-turning except a few ideal drawings, in which the finishing passes of many sections were drawn on the same pair of rolls. Some years ago, Mr. Biederman, a true metallurgical engineer, proposed to publish a work on roll-turning, illustrated with correct drawings, which, together with the corresponding manuscript, I have seen, but the publication of which was given up for reasons unknown to me.

These facts show that there must be some great difficulty in publishing such a work, which is, indeed, actually the case. This difficulty is caused by two circumstances: by the fact that the art rests not on theory, but on wide experience—the men of experience being seldom able, and rarely willing, to publish their knowledge for the benefit of others; and by the fact that if such a work shall really serve a useful purpose, so many drawings are necessary that the cost of the work becomes excessive, and the labor of the author unremunerative. The first circumstance, rather than the latter, has therefore prevented me from writing any complete treatise on roll-turning, though I have often treated of special points, and in 1838 furnished the text and drawings for a small work on rail-making, which was published by Industry and Trade Society of Inner Austria.

For some 25 years I have felt the necessity of such a work as the present, and felt it the more deeply when I observed, as I often had the opportunity of doing, that many men, and especially those from abroad, regarded themselves as indispensable to this or that mill merely

because they possessed the drawings of a few sets of rolls which had been used and liked.

I have, therefore, at last determined to publish this treatise, which, however, makes no pretence to infallibility or entire completeness.

P. TUNNER.

TRANSLATOR'S PREFACE.

In translating the present work I have followed the original text almost literally, and have placed my own additions in their proper places, and as far as possible at the end of the articles to which they belong. The author has written so thoroughly on every detail of roll-turning that there remained little to say except on a few points, the most important of which are the prevention of fins, and the relative advantages of large and small rolls. I have endeavored, as respects the former point, to so refer in various ways to the different methods of preventing fins as to show that, in my opinion, the most important principle of rolling is to prevent them, while giving all passes the requisite draw. For instance, it requires the nicest skill to proportion passes for red short iron, in such a manner that the bars shall be rolled so quickly, and with such draw, that they may be smooth at the finish, without at the same time giving so much draw as to force the metal into the interstices of the pass. I have also advocated the use of large rolls, because they are stronger and less injurious to the bars than small ones, while I have, at the same time, pointed out how the disadvantages of the large rolls may be overcome.

I have, however, added nothing from American practice to the book, because of the difficulty which Herr Tunner mentions, viz., that men who have invented anything advantageous are naturally not inclined to allow their experience to be made public in this way without some advantage in return; therefore I have not mentioned some important American modifications of rolling mill practice, the foremost of which is the application of the three high mill to rolling rails, and peculiar arrangements of the grooves of the rolls, which have been made by the Messrs. Fritz, and adopted in most of our largest mills. I have omitted these, however, with the less reluctance since they are not absolutely essential to a thorough knowledge of the practical principles of roll-turning, and of the design of rolls, and because the main object of this work is to inculcate these principles carefully, and to illustrate them separately by a few good drawings, rather than to offer a collection of examples of various kinds of work. I deem that this object will be furthered by the fact that this work of Herr Tunner offers a careful digest of European practice on almost every point of the art, and believe that American mill managers will find it profitable to study these rolls, designed to work up various irons, many of them widely different from our own, and compare them with those in use at their own mills.

In respect to the nomenclature used, I have been obliged to invent several names, in the choice of which I have made it my object to prefer those names which already had a practical meaning in any similar position—thus, for instance, in the case of "*fillet*," which term I have used to designate the projections which separate Gothic and

similar passes, and whose surfaces are not at right angles to each other, but may be at various angles and of different forms. In the use of the word *groove* I have not held it to be synonymous with pass, but to represent only one-half of the latter, viz., the groove which, in any form of pass, must be turned upon one or both rolls. In some varieties of passes this groove is closed by a fillet on the other roll which projects into it, and the surface of which is turned in such a way as to give the desired form to the bar, generally by means of strong pressure. I have, therefore, called this fillet the "*former*," a term which will, I trust, be found acceptable, both on account of its practical sound, and as clearly expressive of the uses of the part.

The measurements given in the text are in all cases in Austrian inches and parts of inches, because the difference between these and the English is very small indeed. Their exact equivalents may be found in the tables on page 91 and succeeding pages.

All the figures in the atlas are to the scale of $\frac{1}{12}$ natural size, unless otherwise specified. The dimensions are marked on them in Austrian inches, which may be converted into English by means of the above tables.

I have thus endeavored to present to mill managers and roll-turners, and all who take an interest in the art of roll-turning, a carefully prepared system, by the aid of which it may be possible to raise the practice to a higher level.

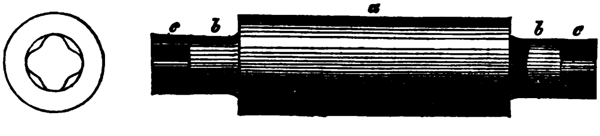
JOHN B. PEARSE.

ROLL-TURNING.

SEC. 1. By the term roll, as used in the iron trade, is understood those cylindrical bodies which are made of cast-iron—sometimes of cast-steel, and also, though seldom, of wrought-iron. These cylinders are furnished with smooth turned continuations at each end, and are accurately placed and borne in a special frame or *housing*. A revolving motion is communicated to the rolls through a shaft coupled to their projecting ends, and this shaft may be driven by a steam engine, or any form of water-wheel, either directly or indirectly, by means of toothed wheels or belts. In each housing are placed at least two rolls, which is the most usual number, although the use of three together is becoming general, while under special circumstances four have been placed in the same housing. In the latter case, however, the rolls are arranged in pairs, and the common axis of one pair need be neither parallel to, nor in the same plane with, that of the other pair.

That part of the roll which is between the smooth turned continuations, and therefore lies free when in the housings, is the part which is used for rolling the iron, and is called the "*body*" of the roll. The smooth continuation, which revolves in a special journal, supported in the housing, is called the "*neck*," while the projecting ends upon which the couplings take their hold, are called the "*pods*."

FIG. 1.



In the figure, *a* is the body of the roll; *b b* are the turned parts of the necks which rest in the journals or brasses, and

c c are the pods which project beyond the journals, and to which either a shaft or another roll is coupled. Every roll must have two necks. The notched part of the neck is unnecessary when no further coupling is wished, and when the upper roll is carried round merely by the friction occasioned by the passage of the iron, both notched ends may be dispensed with, but they are almost invariably added for convenience' sake, as it might be necessary to use the rolls coupled. Such rolls may be called "*drag rolls*," but differ from the coupled rolls merely in not being directly driven. The neck is not always cylindrical in its whole length, but is strengthened or curved outwards where it joins the body of the roll, as is shown in Figure 1. This is especially the case where the rolls must exert a great pressure on the piece to be rolled. The coupled ends are often notched or star-shaped, as in the figure, but may also be made square, or of a circular section, with either two opposite or three equidistant notches, which are moderately deep.

For many purposes—such as rolling plate or polishing hoop-iron—the body of the roll has the form of a smooth cylinder. Such rolls are called *plate or polishing rolls*, and are exemplified in Fig. 1. In other cases, the body of the roll is made up of several cylinders, arranged like steps. Such rolls are called *step rolls*, and, in connection with peculiar guides, are used in rolling flat iron, spring steel, etc. In such cases they save many grooved rolls, which would be otherwise necessary. Figure 33, on Plate III., represents such a step roll, and Figure 34 shows the necessary guides; both figures are $\frac{1}{12}$ full size, and will be described hereafter.

§ 2. By the term "*pass*" is understood those sections of various forms which are produced by the relative position of the different grooves and projections which are turned upon the surface of the rolls; the form of the pass appears sharply marked on looking between the rolls when in position. The term *groove* is sometimes used as synonymous with *pass*; it is, however, preferable to confine it strictly to the *groove* on the body of a single roll. A pass may be formed by two cor-

responding grooves, or by a single groove, into which there fits a fillet or *ring* on the other roll. It is best to call this *ring* the "*former*," in distinction to the term "*collar*," which has reference, as generally used, rather to the fillet, which, while dividing one pass from another, projects into a corresponding groove on the body of the other roll.

Just as two rolls are necessary for rolling, so two corresponding rolls are necessary to form a pass. It is, however, very seldom that a pass is formed by more than two rolls, for if three rolls are in the same housing (three high system), they lie horizontal, parallel, and with their axes in the same vertical plane, and the passes are formed by the middle, alternately with the top and bottom roll; therefore, by two rolls only. It is only in isolated cases, such as the rolling of thin iron tubes, that the pass is formed by four corresponding rolls which work together. Therefore, in all following descriptions, it must be always taken for granted that the pass discussed is formed by two corresponding rolls, unless the contrary is expressly stated. Now, one roll almost always lies vertically over the other, and in the same plane; therefore, in a two high train, where two rolls are used, they are called respectively the *bottom roll* and the *top roll.* In a three high train, however, when three rolls are placed above each other in the same housing, the third is called the *middle roll.*

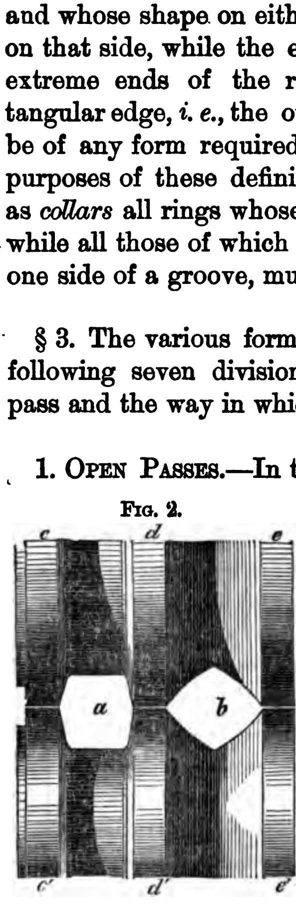
The passes formed by a pair of rolls are usually intended for successive use, *i. e.*, one directly after the other; but other passes, or a set of passes, belonging to an entirely different series, may be turned on the same rolls, in which case the two sets are entirely independent of each other. Between two neighboring passes there must be left a proper space, which takes the form of a projecting rib or ring, and is therefore called a collar. The two corresponding rings at the end of each roll, which form the outside of the last pass, are also called collars. The term *collar*, in its proper sense, means a ring with rectangular edges. In order to distinguish those projections (other than *formers*, and not of rectangular form) which separate the individual grooves of

many varieties of rolls, it will be necessary to denominate them *body-fillets* and *end-fillets* respectively. The body-fillets, so called, are those which are on the body proper of the roll, and whose shape on either side is determined by the groove on that side, while the end-fillets are those which lie at the extreme ends of the roll, and which always have one rectangular edge, *i. e.*, the outer one, though the inner edge may be of any form required by the adjacent groove. For the purposes of these definitions it will be sufficient to consider as *collars* all rings whose edges are rectangular, or *nearly so*, while all those of which each side is obviously turned to form one side of a groove, must be called body-fillets.

§ 3. The various forms of passes may be referred to the following seven divisions, according to the position of the pass and the way in which it is formed by the rolls.

1. Open Passes.—In this form, as shown in Fig. 2, part of the pass is turned upon one roll, the other and corresponding part upon the other roll. The divisions between the passes are formed by a fillet, turned on each roll; therefore the pass (either the *box pass a* or the *Gothic pass b*) is seen to be divided between the top and bottom roll, horizontally and nearly in the middle, as are also the body-fillets, *c*, *d*, *e*, and *c′*, *d′* and *e′*. The body-fillets remain, as it were, as remnants of the original body of the roll into which the necessary grooves have been turned; when the pass is large, however, it is roughly formed in casting the roll. The body-fillets of the top roll sometimes touch those of the bottom roll when it is desirable to preserve the size, and especially the height of the pass unchanged; but, as a rule, more or less space is left between them (a small play is, for instance, observable in the drawing), whereby the

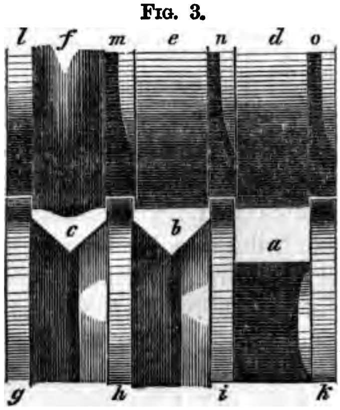
Fig. 2.



pass is left more or less open at the point of division. There are many and very different reasons why this play is left between the body-fillets. Sometimes the object is to save passes, and then the top roll is raised for the first passage of the bar, and lowered as desired for every succeeding passage; but such a procedure should be resorted to only in case of necessity. Again, it often happens that the *body-fillets*, or in other cases the *collars*, are kept apart, in order that the size of the pass may be changed to the size which a test-piece shows to be the proper one. This is the case in finishing rolls, especially those for fine bar iron or rod, but in these cases the play must be small. A third reason is, that such play is a protection against breaking the fillets, to secure which protection the construction described in Article 10 is also desirable.

2. Closed Passes.—In this form, as shown in Figure 3, a groove is cut so deep into the body of the bottom roll that the edge is higher than the total height of the pass. Such grooves are shown in the adjacent figure at *a*, *b* and *c*. Now, in order to obtain the requisite form in the pass, a projection, viz., *former*, must be turned on the upper roll, as at *d*, *e*, *f* (instead of a groove, as in Fig. 2), and this former must fit into the groove in the bottom roll, thus closing the pass. The whole pass is thus sunk into the bottom roll, and the collars proper, viz., *g*, *h*, *i* and *k*, are found only on this roll, as they fit into corresponding grooves, *l*, *m*, *n* and *o*, in the top roll. By this construction the collars of the bottom roll revolve with as little as possible side-play in the grooves of the top roll, but a moderate space is left between the surface of the collar and the bottom of the corresponding groove. This being the case, the height of the pass

Fig. 3.



can be changed at will, as far as the vertical space allows, by raising or lowering the top roll, without at any time opening the pass.

It is evident that it is not absolutely necessary that the groove should be in the lower roll, and the former in the upper one ; but were the contrary the case, the introduction of the bar into the pass would be rendered difficult, and consequently the exertion required on the part of the rollers would be much greater. The arrangement of grooves and formers above described is, therefore, the usual one. We find, however, instances where the grooves are in the upper and the formers in the bottom roll, as shown by Figures 59 and 65, on Plate V. The reason for this exception will be given in Article 26, in which the construction of rolls for angle iron is discussed.

Rolls with closed passes cost more than those with open ones, but possess the important advantage, that the sides of the pass form a certain guide for the bar at its entrance and exit.

3. Half Open Passes.—These are passes which are closed on one side and open on the other, at the pitch line. This form occurs occasionally where difficult and complicated sections are to be rolled, and is illustrated in Fig. 40, on Plate III., by the last two passes on the right. The case also occurs where the immediate bounding lines of a pass would seem to indicate an open pass, which is, notwithstanding, seen to be a closed pass on regarding the remoter bounding lines. An instance of this latter kind occurs on Plate V., in the first two passes (on the left) of Fig. 61. As the above cases have the main characteristics of a closed pass, they are commonly regarded as such, and are not specially classified.

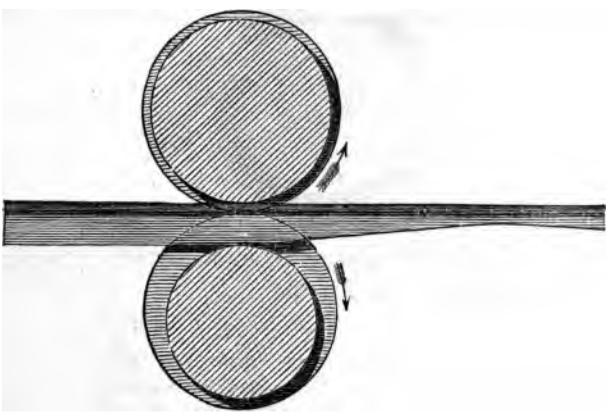
4. Edging Passes.—The position of these passes is generally sufficient to distinguish them, but their main characteristics appear distinctly only during use, as their function is to exercise a powerful pressure on the bar, and because the bar is turned only 90 degrees before its introduction into

such a pass, instead of 180 degrees, as in the use of all others—that is, all others on a single pair of rolls, as in a three high train, nearly finished bars not turned over when they have been brought nearly to the required form. The edging passes are generally closed passes, as is shown in Fig. 40, on Plate III., by the first pass on the left; or on Plate IV., in Fig. 44, by the last pass on the right; in Fig. 45, by the middle pass; and in Fig. 46, by the first pass on the left; or on Plate VI., in Fig. 68, by the last pass on the right; and in Fig. 71, by the pass on the right. These passes may, however, be open, as is shown by the last pass on the right in Fig. 16, on Plate II., and also by the last pass on the right of Fig. 53, on Plate V.

The so-called *adjusting passes*, as well as the *flatting passes*, are named from the nature of the work they do; they resemble the edging passes in their position, and their names are, therefore, mentioned here, while their special description will be presented hereafter.

5. Eccentric Passes.—These are, as the name implies, passes which are turned eccentrically to the axis of the roll. As a rule, only one roll, and generally the bottom one, is

Fig. 4.



turned eccentrically, as shown by Fig. 4, which is a section of a pass for rolling the so-called *fish-belly rails*. Sometimes

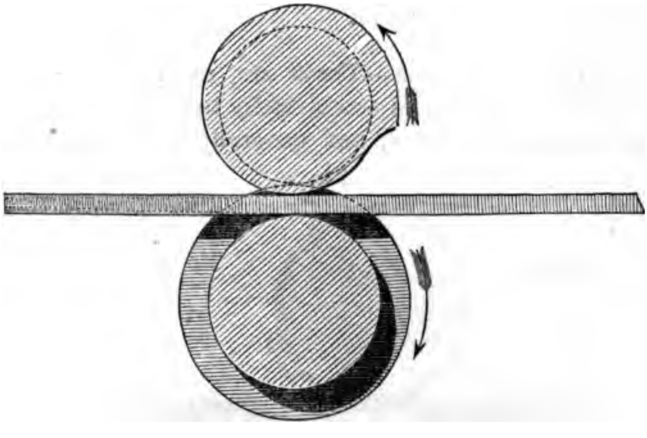
the top roll is turned eccentrically, but it is very seldom that both are so turned.

The bar which has gone through such a pass is naturally of varying depth, and the point of least depth repeats itself at intervals corresponding to the circumference of the bottom of the pass.

It is evident that no more than one such eccentric pass can be used on the same bar, and also that it must be the last. Such passes occasion trouble in rolling, and increase the percentage of scrap and imperfect bars; therefore, they are seldom used.*

6. Spiral Passes are those in which the bottom of the pass is not a circle but a spiral, which, more or less, nearly approaches a circle, and in which the under line is joined to the

Fig. 5.



upper, just before its passage under the latter, by an arc of a circle, as represented in Fig. 5.

* The best method of avoiding such a pass is to so arrange the rolls that their relative position in a vertical plane may be changed during the passage of the bar. Such an arrangement is not similar to that of a tyre mill, as in the latter the rolls can be moved at will nearer to each other; here, however, they are gradually moved to and from each other at a rate and to an extent which are definitely fixed beforehand.

The upper roll is the one usually turned in this way. This form resembles the eccentric, but has the peculiarity that it gives a much more gradual taper to the bar than the latter. This is, therefore, the form of pass applied in the small rolls used for pointing-wire, and in the larger ones which give the wedge shape required by bars for some varieties of springs. The end to be rolled out into a wedge is thrust quickly through the pass as soon as the depression appears, and is then rolled out again directly back into the hands of the roller. A stop on the other side of the rolls prevents the bar from being thrust too far, and it is usual to turn several of these passes of various sizes in the same rolls, in order to be able to taper out finished bars of various shapes and sizes. In order to produce this form of groove, it is necessary to turn an eccentric groove, and then chip off as much metal from its highest side as is required to form the desired spiral.

7. Intermittent Passes.—The peculiar feature of these passes is that the bottom of the pass is made either with notches or projections of various forms, which are applied to either roll singly, or to both, as made necessary by the finished form desired. The notches or projections must, of course, be placed at an equal distance from each other, in order to avoid waste. Such a pass is represented in Fig. 101, Plate X., as applied to the production of "spike-rod." Like the eccentric passes, these can only be used to finish. By varying the form and position of the notches or projections, a very great number of different forms may be produced.

§ 4. Another and a very common classification is made according to the shape of the pass. The following seven varieties are usually distinguished:

1. Gothic Passes.—These passes have the form of a Gothic arch, as represented in Figs. 1 to 7 inclusive, on Plate I. They are always open passes.

2. Flat Passes (to which class the Box Pass belongs).—The form of these passes is a rectangular parallelogram of less

height than width, as shown in Figs. 8 to 12, on Plate I., and in Figs. 16 to 29, on Plate II. A *flat* pass is always a *closed* one ; when made an *open* one, it becomes a *box* pass.

3. Diamond Passes.—These are square in their general form, and are represented in Figs. 13 and 14, on Plate I., or better in Fig. 30, on Plate II. They are, with very few exceptions, open passes.

4. Oval Passes.—These are shown in Fig. 35, on Plate III., along with diamond passes ; they are, like the latter, almost always open passes.

5. Round Passes.—These are similar to those drawn on Plate III., in the last pass of Fig. 35, and in the right half of Fig. 36. They are always constructed as open passes.

6. Polygon Passes.—In this division are included principally hexagon and octagon passes. The latter form may be found in the left half of Fig. 36, on Plate III. These are always open passes, and are often included in the following class.

7. Shapes. Under this head are included all those passes which are differently formed from any of the preceding, and among them there exist very complicated forms. As a rule, these passes are of the closed form.

§ 5. In addition to the two methods of classifying passes, as above described, they may be individually named according to the work which they are to perform. Considered in this light, the four following kinds of passes may be distinguished :

1. Welding Passes.—By this term is understood those passes through which the piece is rolled while at a welding heat. These are naturally the first passes, and generally the first three, and are made with a very great draw or reduction, in order that the pile may be powerfully compressed. Their surfaces are often roughened with the chisel, in order that they may take firm hold of the pile. The forms most gener-

ally given them are the Gothic or flat, with the exception that, in the case of a good many large shapes, the form of the first pass must be accommodated to that in which it is necessary to make the pile.

2. Drawing Passes.—In these the section of the pile is often not at all regarded, the main object being to reduce it as fast as possible. This character is especially marked in rolls for merchant bars. In rolls for rails, I beams, etc., the final form cannot be disregarded; hence in these, and in all similar cases, the rapid drawing down of the pile or bar must be accompanied, to some extent, by a shaping process. These passes are used immediately after the welding passes, and are often similar to them in form. The Gothic form is, however, the most useful, as it admits of a very heavy draw, as will be hereafter explained. Any number of these passes, up to 10 or 12, may be used successively in one heat. Both the above classes are often collectively included in first and second roughing passes, and may be turned together on one pair of rolls, though often constructed on two.

3. Shaping Passes.—These mould the bar gradually to the desired form, at the same time reducing its sectional area. In the first of these passes the reduction is great, while the bar remains hot and soft, and, consequently, flatting passes are often used to increase the reduction, as well as to assist in shaping. The number of these shaping passes varies greatly. In the case of the simpler forms they are constructed as the last preparatory or roughing passes, but when complicated shapes are rolled they often form the necessary welding passes. Such a case is presented in Fig. 82, on Plate VIII., which delineates the passes for large deck beams, or T iron.

4. Finishing Passes.—The object of these passes, which are the last in the train, is to complete the form of the bar, and make its surface smooth and clean. The reduction given these passes is very small, and the contraction of the finished bar on cooling must be provided for in the last one. Strictly speaking, the last pass only could be called a finish-

ing pass, but the piece is often rolled several times through it, as in the case of the heavier round iron. Strictly speaking, the last pass only could be called a finishing pass, but the piece is often rolled several times through it as in the case of the heavier round iron. Sometimes two finishing passes are placed side by side, or a rough space is left for the second, in order that the latter may be ready for use, or easily turned up, when the first is worn out. Some of these passes always precede the finishing pass on the same roll. When the terms first and second roughing are used, most of these passes are included with the finishing passes proper, under the term of finishing passes.

The following varieties may also be named from the nature of their service:

5. Flatting Passes.—These are distinguished from all others in that they greatly increase the width of some part of the bar rolled through them. To this end, they must exert a considerable draw, and in this respect, as well as in their position, they are ranged with the *edging* passes. They are extensively used in rolling shapes, such, for instance, as T rails.

6. Adjusting Passes.—These are used, when the finishing is accomplished with *step* or polishing rolls, in order to give the bar the desired width, and finish its corners. To accomplish this end, the bar must be rolled on its edge, and the pass, therefore, must be made high and narrow. If the bar is to be finished with rectangular corners, the use of a special guide arrangement, as shown in Fig. 34, on Plate III., is often preferred to that of the adjusting pass; but the use of the latter cannot be well avoided if the corners of the piece are rounded off. These passes are, with few exceptions, open.

§ 6. If we regard these respective divisions more generally, we find that the six kinds of passes described in § 5 separate themselves into roughing and finishing passes. This is especially the case in ordinary bar-iron rolls, and these designations are quite convenient. This being the se, the rolls which contain these respective passes can be

respectively called roughing and finishing rolls, which are the practical designations. When there are two sets of roughing rolls, those which contain the welding and part of the drawing passes are called the first roughing rolls, while those which contain the other drawing and part of the shaping passes are called the second roughing rolls, and those containing the rest of the shaping and the finishing passes are called the finishing rolls. These terms agree with those used in forging, viz., the *finishing* or *polishing* the forging which has been previously *drawn down* out of a larger pile or ingot.

As we have stated above, the passes necessary to the production of any desired shape need not be confined to two rolls only. They are sometimes all turned on a single pair, but much more generally divided among three, or sometimes five, or even a greater number of pairs. The passes are thus divided, not only to avoid too great a length between the necks, but also to get more room for the men by separating the pairs. Sometimes it is an object to be able to alter at will the height of certain passes, particularly the last two finishing, or to get a different angular velocity (*i. e.*, surface speed) for special passes, which object is attained by grouping them as far as possible on different rolls. In rolling wire rod, it is necessary that the bar should be in several passes at a time, and it is therefore desirable to so separate these passes as that they may be conveniently reached and worked.

It is, also, not necessary that a pair of rolls should be turned exclusively for one section, but there may be upon the rolls passes of widely different sizes of the same, or even of an entirely different kind.

When a number of rolls, with their respective housings, are set up in a continuous line and so coupled that their individual velocity must be the same, the combination of rolls and housings is called a *train* of rolls. The various trains are named according to the kinds of iron they produce. Thus a train which receives squeezed or hammered balls and transforms them into puddle bar, is called a puddle train, while a series of rolls for rails is similarly called a rail train. The

trains devoted to round or square iron, small bars of fancy sections and angle irons, are, in a general way, called merchant trains, which, in a large mill, may include heavy and light bar, or wire-rod trains, etc.

§ 7. After the foregoing general view and classification of the passes which commonly occur in a set of rolls, it will be most useful to consider the way in which the individual passes act upon the iron, before their construction in detail is discussed.

A pass, no matter what its form, can exert a direct pressure on the iron only in a perpendicular direction, at right angles to the axis of the roll. This pressure diminishes the height of the bar rolled, but does not materially affect its width. Now, as this reduction of height occasions a corresponding increase of length, we may call this pressure the draw pressure. The difference in section between successive passes is called the *draw or draught*, and is occasioned mainly by the difference in height of the respective passes. It is clear that the width of the bar cannot be *directly* affected, since the sides of the pass must be parallel in a horizontal (though not necessarily in a vertical) direction, in order to permit the passage of the bar. Therefore, the sides of a pass can exercise no direct pressure on a bar, and cannot take hold of one wider than their own distance apart. Such a bar can scarcely be introduced, and the excessive iron is forced into all the interstices of the pass, forming fins, which are torn off, or remain to materially injure the surface of the bar.

In order to facilitate the rolling, it is necessary to construct each of the successive passes a little wider than the preceding. This difference in width varies from almost nothing to an eighth of an inch or more, according to the size and form of the passes. It follows, therefore, that the successive passes should be made wider and wider, and this is indeed commonly the case when the bar is either not turned over at all, or turned 180 degrees after each pass. It would, however, extremely inconvenient to thus widen any large number ccessive passes, and it becomes necessary to intersperse

flatting passes (*vid.* § 3) among the rest; for these passes the bar is turned only one quarter over (*i. e.* 90°), whereby the former thickness or depth of the bar becomes its width, and the former width becomes its depth. The pass succeeding the flatting pass is then narrower than the one which preceded the same, and forms the starting-point of a new series, which is again intercepted by a flatting pass, when the width of the grooves becomes inconveniently great. There are, hovever, some forms of passes, such as the Gothic and Diamond, in which the bar must be turned quarter over at each pass, and, consequently, the depth and width of the bar interchange positions at each pass. Here the successive passes must be so proportioned that the height or depth of one pass is a little smaller than the width of the next. This arrangement of passes is so important that it is termed by Truran, "the fundamental principle of rolling."

In flat passes, however, and in some shapes, the necessity of increasing the width of the successive grooves may be partially and even wholly avoided, by slightly increasing the width of each groove from the bottom of the same, outwards. This construction enables the pass to take in easily a bar which otherwise could scarcely be introduced, and is of additional use, in that it greatly facilitates the exit of the bar.

Although the vertical draw-pressure is the only one directly exercised by the grooves, yet a side-pressure is indirectly occasioned, since the iron is more or less soft and yielding, and is, therefore, not only drawn out lengthwise, but also bulged out sidewise and pressed against the sides of the pass, if the latter is not wide enough to allow the pile or bar to spread without contact. This is seldom the case, and hence the sides, in preventing further spreading, exercise a pressure opposed to the draw-pressure. Let us, therefore, call the former force the side-pressure. Now, this side-pressure will be greater as the draw is greater, the width of the pass remaining the same, and *vice versa,* the greater the width the less the side-pressure, the draw remaining the same. The side-pressure must be correctly proportioned to the draw or draw-pressure, in order that the bar may take

the exact form of the pass; when the former is too great, the iron is forced into the interstices between the body-fillets, or between the collars and the formers, which necessarily cannot touch each other, and a fin is formed as well in the case of closed as of open passes. Therefore, when the piece must be quickly reduced, as in drawing or shaping passes, a powerful draw must be employed, and, therefore, the widths of all the passes should be made proportionately greater, on account of their considerable width as related to their depth. For instance, the oval passes are extensively used in reducing small sections.

This relation between draw and side pressure is obvious, and, therefore, easily understood. It is, however, not so clear why a piece of iron which is at a higher heat, or which, on account of its chemical or physical character, is softer than another, widens proportionately less, and hence occasions less side-pressure than the latter piece, which is harder, and resists the draw more strongly. The following experiment proves, however, that such is actually the case: Four bars, two of which were of soft iron and two of steel, were rolled through the same closed pass into flat bars 1 inch wide and $\frac{3}{8}$ of an inch thick. An iron and a steel bar were brought to a cherry red heat, while the second iron and the second steel bar were brought nearly to a welding heat. All were then passed through polishing rolls, furnished with accurate guides, and reduced at one passage to a thickness of $\frac{3}{16}$ of an inch. In this way all were exposed to the same draw-pressure, while entirely at liberty to expand laterally. The result was, that, in the case of the iron, that bar which had been rolled at the lowest heat was several per cent. wider than that rolled at the high heat, and the same was true in the case of the steel bars; it also appeared that the steel bar was in each case somewhat wider than the iron one which had been rolled at the same heat. The latter result was especially surprising, but its correctness cannot be doubted; its accuracy is further proved by the fact that it is generally known among merchant iron rollers that in rolling long hoop iron the rear end of the bar, which grows comparatively cool

before it is rolled, is always appreciably wider than the other end, even though it remains somewhat thicker.

It is easier to understand the fact that if the same pass is turned on rolls of different diameters the iron will be lengthened more, and widened less, in the rolls of small than in those of large diameter. The same principle applies here as in the working of a hammer with broad or narrow die: the narrower the die the quicker is the piece drawn out; and if it is desired to forge a thin plate under a broad die it must be forged out crosswise, and with frequent turning under a special narrow tool, which thereby supplies the place of a narrow die.

§ 8. At first sight it appears that it would be the best and most natural arrangement to turn one half of a pass on the top, and the other on the bottom roll. In this case the half of the depth (sometimes the half of the sectional area) of the pass would be under, and the other half over, a horizontal line drawn midway between the axes of the rolls, which line is called the *pitch line.* If the pass were thus divided any force would easily turn the bar, at its exit, either up around the top roll or down around the bottom roll. This sometimes happens to the slabs of a large pile, when the bottom or top ones are torn off and curled up. Now, if a bar, or a single slab of a pile happened so to curl up, it would naturally not only make the same worthless, but also be likely to break a roll, or occasion other damage, such as destroying pipes or guides, etc., and, therefore, special appliances must be used to prevent these accidents. But if the depth of the pass was equal above and below the pitch line, these appliances would be necessary on both rolls—an arrangement which would not only be difficult, but also inconvenient; therefore the depth of a pass is always so divided that a little more lies under the pitch line than above it, when the pass is designed for ordinary two high rolls. In other words, the diameter of the groove on the top roll is made somewhat greater than that of the other groove on the bottom roll. The upper surface of the bar is, therefore, lengthened or drawn out more than the under one, which causes a tendency

in the bar to curl down toward the bottom roll. Thus it becomes possible to use only one set of appliances, or guards, on the under roll, as there is now no danger that the bar will curl around the top roll.

There are, further, two kinds of these appliances; the one is horizontal and projects into the pass, and is called a guard; the other kind stands vertically behind the pass, and on each side of it, so as to prevent the bar from swerving to the side. These upright pieces are termed guides, and are supported on a cast-iron plate called the "*bearing plate,*" the front edge of which sometimes takes the place of a special guard, as detailed below.

The guards consist, in their simplest form, merely in a cast-iron plate, which is laid behind the rolls, and so formed that it projects into each pass, though not accurately fitted to the same, thus loosening bars from the rolls if they have a tendency to curl down as they come out. This cast-iron plate, or "*bearing plate,*" also carries the guides, as mentioned above. When, however, the section of the pass is small, or its form complicated—in which case it would be difficult to loosen the bar—it is necessary to lay upon this cast-iron plate a flat wrought-iron bar which has the exact shape of the pass, and closely fits the curve of the roll. If the pass is irregular—as an eccentric pass, for instance—it is best to place a second guard under the first, slanting up against the roll from a bar placed under the bearing plate. This guard is kept by its own weight against the bottom of the groove.

If the difference between the diameters of the working surfaces of each groove is made too great, the guards are unnecessarily strained and rendered useless, while the bar itself is injured by the unequal draw of its surfaces. The proper difference of the diameters varies with the character of the iron and the circumstances of its treatment, and must be carefully ascertained and regulated. The following rules represent the general practice:

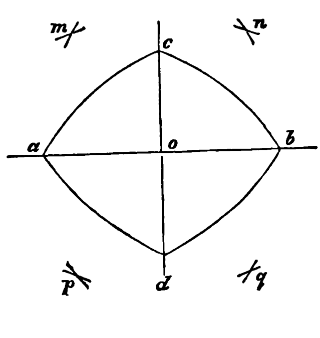
In the case of plain open passes the diameter of the top ll is from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch greater than that of the bot-

tom roll. In the case of closed flat passes the groove in the bottom roll is cut so deep that its diameter is from $\frac{1}{12}$ to $\frac{1}{8}$ of an inch less than that of the former which closes it. In rolling shapes it sometimes happens that more than $\frac{2}{3}$ of the pass is under the pitch line. In the case of larger roughing passes and of flatting or edging passes, the differences of diameter of the working surfaces vary from $\frac{1}{4}$ of an inch to 1 inch, and even more.

In all the drawings of grooved rolls, or of passes, which will be given hereafter, the diameter of the working surface of the grooves will be added in figures, or the pitch line of the pass will be drawn in. The classification found most convenient in treating the construction of the various passes in detail is the one described in § 4. It has been my aim to discuss in the following pages the construction and the draw of series of passes, to treat of their application, and, as far as possible, illustrate all descriptions of rolls by means of accurate (working) drawings to the scale of $\frac{1}{12}$, appending the respective passes in full size.

§ 9. The Gothic passes are very important, are frequently used, especially as roughing passes, and are constructed and applied in many different forms. They possess the advantage of being simple and durable, while they do not chill the bar irregularly, as their form approaches a circular one, and, on the other hand, as their form is so nearly square they draw the bar equally on all sides. This form was described by Karsten in the last edition of his work on iron, in Figs. 1 and 2, on Plate LIII.; but the construction there given is entirely incorrect, as the depth of the pass is much greater than its width, and, so far as my experience goes, this form has never been used.

Fig. 6.



A very simple and practical construction is shown in Fig. 6, the depth and width of the pass being supposed to be given.

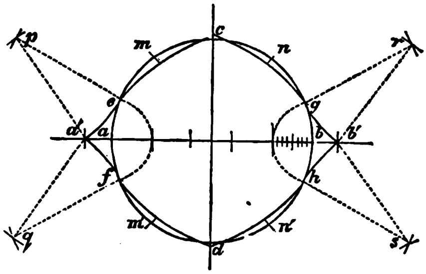
To construct the pass, draw the straight lines *a b* and *c d* at right angles to one another; lay out from their intersection at *o* the half of the given width on each side in *a* and *b*, as well as the half of the given height above and below the horizontal line in *c* and *d*. Then with the radius *a b* describe from the point *b* an arc near the point *m*. With the same radius describe an arc from *d* which intersects the former at *m*. Further, with the same radius describe from the point *m* the arc *b d*, which is one side of the pass. By the same process repeated from each point, *a c* and *d* in turn, the points *n p* and *q* are found, and the respective arcs described, as shown in the figure. The sharp corners at *a* and *b* must be rounded off, as shown in § 10, Fig. 9.

In this construction the first point to be considered is, whence the given depth and width are derived. Now, the absolute dimensions of the first pass are regulated by the size of the pile to be rolled, or, *vice versa*, the size of the piles must be regulated by that of the first pass in the roughing rolls on hand. In most cases it suffices to give the first Gothic pass such dimensions that a pile of 5½ to 6 inches high can be taken in. This is the practice for puddle blooms and small piles, but for larger piles the Gothic pass is seldom used. The only case, in my experience, in which this form was used with more than 7 inches average diameter, was in an English mill, with the special purpose of taking in the puddle balls direct from the furnace, in case the forge hammer should suddenly break down. In order to have no difficulty in rolling the balls, they were made rather cylindrical than spherical. It generally suffices to give the first pass an average diameter of only 5 inches, as when piles larger than this are rolled, the rolls can be opened for the first two or three passes by raising up the top roll for, and lowering it after each passage of the pile.

Further, the usual difference between the depth and width of a pass is mostly about one-sixth of the average diameter of the same, hence about one inch for the first and largest passes. Therefore the depth and width of the first pass may from these data be easily supplied in special cases.

Another method of construction is given in Fig. 7, which is extensively used in Upper Silesia and Austria, and originated with the Nestor of Continental rollers, Mr. Talbot. In this method, a circle of the average diameter desired is used as the basis, and is hence called the Construction circle. In this construction circle the horizontal and vertical diameters *a b* and *c d* are drawn and continued on each side beyond the circumference. The horizontal diameter is divided into five equal parts, and one of these parts is subdivided into eight. The lines *a a′* and *b b′* are laid off of a length equal to five of these subdivisions, and the points *a′* and *b′* denote the extreme horizontal width of the pass. With a radius of $\frac{1}{8}$ of the diameter *a b*, lay off the points *e f g* and *h* from the points *a* and *b*; then, with a radius of $2\frac{5}{8}$ fifths of *a b* (*i. e.*, $\frac{21}{40}$ of the diameter), describe arcs from *a′* and *b′*, and mark the points of intersection at *m n*, *m′* and *n′*. These four points are the centres of the required arcs, *h d*, *d f*, etc., which form the sides of the pass, and are described from these points with the radius *m h* or *n f*, etc. From the points *g* and *b′* describe, with a radius equal to $\frac{3}{8}$ of the diameter, two arcs cutting one another in the point *r*, and from this point, with the same radius, describe the arc *g b′*; repeat the operation for each arc *b′ h*, *e a′*, and *a′ f*, and the pass will be properly closed.

Fig. 7.



The constructions illustrated in Figs. 6 and 7 * are chiefly used for puddle roughing rolls, but for the roughing rolls of a merchant or guide train, the following construction is pre-

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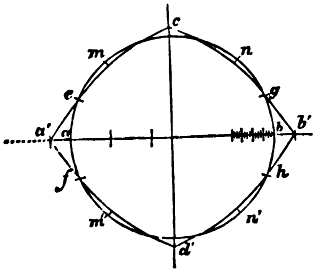
* It is not possible to explain either these or any following forms of passes on any mathematical or physical principles; but the various constructions given represent forms which have been gradually determined by experience, while a fixed and approved measure is given for each curve and line which forms any given pass.

ferred. This is shown in Fig. 8, and differs from that shown in Fig. 7 in that the points e and f and g and h are joined respectively to a' and b', not by means of arcs of a circle, but by straight lines, and that the extension of the horizontal diameter of the construction circle, and consequent width of the pass, is somewhat less. The horizontal diameter $a\ b$ is divided as before into 5 equal parts, but one of these is subdivided into 16 parts, and the lines $a\ a'$ and $b\ b'$ are laid off with a length equal to 8 of these subdivisions. The four points, $m\ m'$, n and n', are are found as before, from a' and b', but with a radius of $2\frac{5}{16}$ fifths of $a\ b$ (*i. e.*, $\frac{37}{80}$ of the diameter); the arcs which form the sides are then further described, as in Fig. 7. The form of Fig. 8, as compared with that of Fig, 7, shows a little less width and a greater height; the pass is, therefore, better closed at the sides, a form which is desirable for the more compact material (*i. e.*, pile of flat bars) to be rolled, which contains by far less slag than puddle balls, and out of which the slag is rolled far more easily than out of the latter, because it is hotter.

FIG. 8.



For the roughing rolls of a bar train in which the draw (or draw pressure) must be very great, in order to reduce as quickly as possible, when for this reason, the use of oval passes does not seem desirable, it is advisable to draw the arcs described from a' and b', and intersecting the circle at $m\ n$, m' and n' with a radius of $2\frac{6}{16}$ fifths (*i. e.*, $\frac{38}{80}$ of the diameter), whereby the depth of the pass is slightly reduced.

§ 10. The draw or draught of a pass is, as explained in § 7, a difference between its area and that of the next larger pass; and in the case of the Gothic form, as well as in that of some other forms, the width of one pass must be a trifle in excess of the height of that which precedes it. The difference varies with the absolute size of the pass, amounting

in small passes to about $\frac{1}{12}$ of an inch, and in large passes to about $\frac{1}{4}$ of an inch. A greater excess is found only in the first two passes of puddle roughing rolls, as it is necessary that these should have ample width in order to safely take in blooms which are irregularly formed. In these passes the width of one is often from $\frac{1}{3}$ to $\frac{2}{3}$ of an inch greater than the height of the preceding. The draw must also be regulated by the quality of the iron to be rolled. A good quality bears without injury a strong pressure, and rolls smoothly under a draw which would tear a poor iron to pieces. It is, however, scarcely necessary to remark that an unnecessarily light draw delays the rolling greatly, and, therefore, increases the amount and cost of the required labor. The draw should obviously be as heavy as possible, but local experience only can guide to a correct construction. Hence this local experience is exceedingly valuable, but is too often inaccurate, and even imaginary.

The draught of Gothic passes is on the average about $\frac{1}{10}$, but increases with the size of the passes up to $\frac{1}{9}$ or $\frac{1}{8}$. Small passes, with a draw of $\frac{1}{8}$, would be useless, as such a reduction would cause the formation of fins—thin, riband-like longitudinal projections along the sides of the bar, where it has been forced against and between the body-fillets. With reference to the diameter of the construction circle, a simple and approved construction for the Gothic passes of puddle rolls, which is used at many works, is the following: 6 inches, 5, $4\frac{1}{4}$, $3\frac{3}{4}$, $3\frac{1}{4}$, $2\frac{7}{8}$, $2\frac{6}{8}$, $2\frac{4}{8}$, $2\frac{2}{8}$, 2, and $1\frac{3}{4}$ inches diameter of the circles of the successive passes. Here we see immediately that more attention has been paid to simplicity than to accuracy. The first, or sometimes even the second, of these passes is skipped when the balls have been made too small, while the smaller passes are only used as far as the kind of puddle bar, which is to be produced, requires. For instance, it often happens that the five passes, from that of which the construction circle is 5 inches diameter to that of which it is $2\frac{7}{8}$ inches diameter, are the only ones used when the balls are formed in the furnace to a weight of about 1 cwt., and rolled into bars 3 inches wide. The above reduc-

and drawing passes for bar-iron rolls, even of quite small size, therefore Fig. 5, on Plate I. is added; this represents the roughing rolls of a bar-iron train, in $\frac{1}{12}$ full size, while the corresponding passes are shown in full size in Fig. 6. These passes are drawn according to the method described in § 9, Fig. 8. Figure 7, on Plate I., represents in full size merely the roughing passes of a train for small bar-iron, which are constructed similarly to those of the puddle rolls shown in Figs 1 and 2, on Plate I. Both of these rolls, viz., Figs. 5 and 7, are Styrian, and the latter is in use at Neuberg.

As may be seen in the drawings, the draw of these passes is about the same as that of the puddle rolls above described. Taken strictly, one would expect a less draw for small bar-iron, because the latter is pretty solid, and especially because it is of great importance that the finished bars should be free from imperfections; but the Styrian iron bears quite a heavy draw, in spite of its frequent steel-like quality, and the absolute draw of the puddle rolls above described was not very great. At other mills, the draw of the same rolls is frequently much lighter; in which case single passes can be often skipped, where experience has shown this to be admissible.

If the grooves are large and deep they weaken the roll very much, by reducing its sectional area, and this is especially the case when they are near the middle, as this is the weakest point. In such cases the diameter of the roll must be so great that its diameter in these grooves is greater than the diameter of the neck, and the passes themselves should always be placed next the neck. For these reasons the largest Gothic passes are often placed at one end of the rolls, then the second, and so on; but in the case of small rolls, or any in which the diameter may be proportionately too small, it is advisable to place the first and second passes at one end, and the third at the other, the succeeding passes decreasing in size toward the first two. Many rollers think that the first or welding passes should be nearer the centre of the rolls, as the slag which is squeezed out of the pile

might get into the journals; but it is much more important to avoid breakages by making the rolls strong, than to avoid a hypothetical injury to the necks or journals, especially as the latter can be easily prevented by placing an iron shield or *cinder-plate* between the rolls and journals. Sometimes the roll is especially notched to receive the cinder-plate, while it is often the case that the end-fillet of large rolls sufficiently protects the neck.

The use of Gothic passes in three high trains for small bar is quite frequent, and very advisable, as the arrangement of the passes presents no difficulty. The construction of the passes remains the same, but it is necessary to make the diameter of the top roll about $\frac{1}{12}$ of an inch greater, and that of the bottom roll about $\frac{1}{12}$ of an inch smaller than that of the middle roll. In this case the guards rest on bearing-bars before the middle and lower rolls. If hanging guards are used, the top roll should also be about $\frac{1}{2}$ inch smaller than the middle roll. In a forge near Leoben the three high system is thus used for the puddle rolls, and with marked success.

The last Gothic pass represented in Fig. 7, Plate I., has a diameter of nearly $\frac{3}{4}$ of an inch (or $\frac{1}{2}$ inch length of side); but it is seldom that the diameter is less than one inch, as the pass, when so small, would not roll accurately enough, especially if the sides were much curved. When the drawing passes must be so small, it is better to use oval and diamond passes alternately.

§ 12. Box passes are used as welding passes, when the pile is large, or its form varies considerably from a square. Such passes are, of course, always open ones, with rounded angles, while the sides of the body-fillets form an obtuse angle with the bottom of the pass, as shown in Plate II., Fig. 16. The grooves of the top roll are notched or furrowed, in order that they may take a better hold.

When the section of an open box pass does not differ materially from a square, it is often so constructed that the pile may be passed once, turned quarter over, and returned through the same pass, which has been somewhat closed. In this way a few passes may be saved, and sometimes the

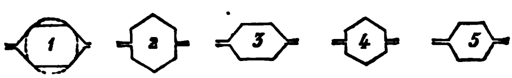
able, by the adjustment of the rolls, to bring the passes into the desired truly round form.

The constructions described in Figs. 17 and 18 are used without guides; for if a guide is used, the bar must be finished at a single passage, as the guides do not possess the necessary accuracy when the bar is very nearly round. The distinction between guide rolls and those without guides is not a sharp one. In many mills, all round bars under an inch thick are rolled with guides; in others, rounds as low as ⅜ of an inch, or even less, are rolled without guides, the bar being guided by hand. The diameter and the required length of the bar determine the kind of rolls to be used; for the longer the bar becomes, the more uncertain becomes its guidance by hand, even though a second roller helps to guide.

Roughing rolls for large rounds are similar to those shown in Figs. 5, 6, 7, 13, and 14, on Plate I., all which have been already described. Finishing rolls for large rounds have been described in the first part of § 17, and represented in Fig. 36, Plate III.

§ 19. Polygon passes are employed almost exclusively in the hexagon or octagon form, to finish bars of similar section. The corresponding roughing rolls are, like those for rounds, furnished with Gothic passes. When the section is large, as for instance 1½ inches between the sides, and when the corners are to be rolled sharp and the sides smooth, it is best to use three shaping passes, a plan which is preferred by Mr. Baildon, of the Donawitz mill, near Leoben.

Fig. 19.



These are shown in Fig. 19, in which the height of one pass is always somewhat less than the width of the next succeeding, since the bar is turned one-quarter over, after each passage through the rolls. The finishing pass, which has the form of the polygon, may be placed similarly either to No. 4 or to No. 5 in the figure.

In the case of light bars of polygon form, one shaping pass is sufficient, which should have nearly the required form; but the width of this pass should be greater than its height, in order that a sufficient draw may be afterwards applied in the finishing pass.

The draw of these passes is proportioned according to the general rules which have already been laid down for the purpose.

The rolls drawn in Fig. 36, Plate III., contain merely the finishing passes for octagonal bars; these passes are not intended to be used successively in the order given, but each pass is intended to finish a bar of octagonal form, but of different weight. The details of these rolls are, like those described in § 17, not very clear, on account of the small scale.

§ 20. Shapes include a very great and perhaps almost unbounded variety of passes, the construction of which varies of course with their form.

In recent times there have been so many, and such quite new applications of iron to buildings and machinery, that the number of shapes has increased enormously.

Their number is, indeed, so great that it is impossible to treat of them exhaustively, or, indeed, to arrange them satisfactorily, according to a few generic forms. It is, therefore, necessary to be guided by the practical importance of the chief forms, in the selection of so many of them as it is desirable to describe in detail. By handling, thus, first and in greatest detail, the forms which occur most frequently in general practice, a far greater amount of useful information may be imparted, than would be possible were the book to be unduly filled up with the discussion of shapes which are sometimes exceedingly difficult to construct, are never produced in large quantity, and are never likely to become a lucrative product of a mill.

The most important and frequently occurring forms are naturally rails, tyres, angle iron, deck or T, and I beams, some half round forms, such as felloe iron, etc., and finally some of the principal varieties of spike and sash iron; these will be

taken up respectively in the above order. But before the rolls for the individual kinds are described, it will be necessary to preface some general rules for the proper construction of rolls and passes. The composition, size, and form of the various piles for rolling must, therefore, be first considered, as these details stand in intimate connection with the system of passes used.

§ 21. A large original section of the pile contributes quite essentially to the good quality of the interior of the finished product, as well as to its handsome appearance; but the greater the original sectional area, the greater are the costs of manufacture. Therefore, economical reasons render it necessary that certain limits should be set to the size of the pile. The larger the section of the finished product, the less it is possible to enlarge the original section. The billet out of which wire rod $\frac{5}{24}$ inch thick is rolled has a section over a hundred times as large as that of the rod, while the piles which are made up for rails, tyres, I beams, etc., have often scarcely five times the sectional area of the finished product.

When these large shapes are heavy, and the reduction of area must consequently be small, it is necessary, especially if the form is somewhat complicated, to give the pile a special form corresponding to the finished shape. This is done in order to employ fewer shaping passes. In the adjacent Fig. 20, A and B represent two piles of this kind for an I beam 12 to 18 inches deep, and of the form represented by C.

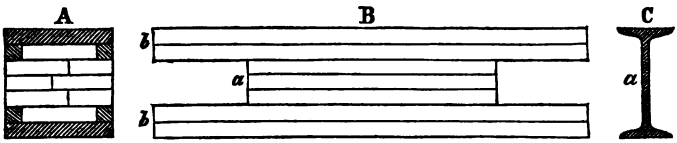
FIG. 20.

It is also necessary to consider the quality of iron demanded by the individual parts of the pile, and in putting the latter together, that special goodness or quality be present in any part where the rolling or subsequent use makes a quality desirable, and, on the contrary, that a cheaper ...er quality be used for other parts, so that the cost

of the product may be as small as possible. Those parts in the above figure which are marked *a* and *b* are made of iron which has been once or twice reheated and rolled (usually designated as Nos. 1, 2, 3, or "best," "best best," "best best best," according to the whole number of times the iron has been rolled). The parts *c*, on the other hand, are made of puddle bar.

Fig. 21 represents another feature of the formation of a pile, which, though not exactly made necessary by the passes used, still affects materially the economy of their working.

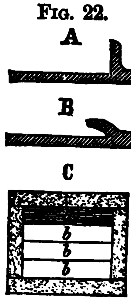
FIG. 21.



The section A of the figure is nearly square; the side view B shows, on the contrary, that the top and bottom bars are considerably longer than the middle ones. This is on account of the fact that, were the bars equally long, the middle part *a* of the finished beam *c* would be longer than either flange, and would have to be sawn off to make a beam both ends of which were of the proper form. The pile is, therefore, arranged as above, in order to economize material. The hatched parts are, further, No. 2 iron, while the rest is puddle bar.

Even the direction of the fibre of individual parts of the pile must be considered in arranging the latter. For instance, when single-lipped chairs were rolled at Zöptau, in Moravia, to the form A, Fig. 22, the individual chairs being sawed off and the lips bent down simply, as shown in B, very many lips or feathers were broken off, so long as all parts of the pile were arranged as usual, and so that the fibres all ran in the direction of the length of the pile, while the feathers were bent across this direction. This difficulty was obviated by taking out the longitudinal bar from the

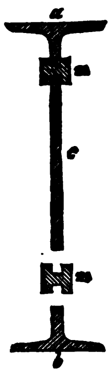
FIG. 22.



position *a*, and laying it in its place and next each other narrow strips 4 inches wide, with the fibre running crosswise. These strips were cut from No. 3 bars, while the other parts, with the exception of the three layers of puddle bar, *b*, *b*, *b*, consisted of No. 2 iron.

It must also be here remarked that very large shapes are not usually rolled out of a single pile, but are composed of parts rolled separately, and afterwards welded together. Thus, for girders of a depth of two feet or over, the top and bottom flanges, *a* and *b*, are rolled separately, while a wide bar or plate, *c*, forms the web, the respective pieces being joined by the double channel bar, *m*. The flanges are usually heavy deck beams (T iron), of a strength corresponding to the size of the desired girder. The parts are fitted to each other, as shown in the adjacent Fig. 23, are held together by clamps and screws, and are then welded, piece by piece, along both lines of junction at once. The distance welded at each heat is about 1 foot. The girder is supported on rollers, so that it may be moved in the direction of its length. At right angles to this line of rollers a small railroad is laid down, just beside which latter is placed a peculiar anvil. Two small blacksmith's fires, with several tuyeres, are borne on the railroad, one on each side of the girder, so that they may be pushed together under it, or apart, and away from it. When by their use a welding heat has been got up on both sides of the girder, they are pushed back, and the part heated is rolled upon the anvil, when it is struck and welded by two 40-pound hammers, worked from a shaft running crosswise underneath them. To insure a good weld the channels in the double-channel bars need not be more than ¼ to ⅓ of an inch deep.

FIG. 23.



§ 22. In the case of all passes described up to § 19, inclusive, the construction could be, and actually was, so carried

out that the pressure was entirely equal toward each side. The bar had thus no tendency to bend sidewise ; the diameter of the grooves was, however, so proportioned that the bar might be bent slightly downward against the guards. As far as possible, the same rule is observed in rolls for shapes ; and if a shape may be divided vertically by the centre line into two equal parts, the observance of this rule occasions no difficulty, and the relation holds good that ordinarily obtains between the draw and the spread of common bar iron. The only difference between the cases is that in the latter the draw is uniform across the width of the bar, while in the former it must necessarily be quite different, in order to form the required shape. The question naturally arises, how great may the difference of draw be allowed to become?

If no draw was applied to some parts of the bar, the form desired would be very quickly attained by the use of a few passes. If, for instance, the attempt was made to roll the channel iron in Fig. 24 simply by compressing the middle part, *a* or *b b*, of a flat bar, the result would be that the sides or flanges, *c c* or *d d*, would also be drawn out—not so much, indeed, as the middle or web, but more or less according to the quality of the iron, and would, therefore, become ragged, or, even in the case of the very best iron, would at least lose their proper form. Therefore, in order to preserve the proper shape, it is necessary to draw the flanges also, to fill out the whole pass thoroughly with iron, and to use for the flanges a specially good iron, which has been reheated and rerolled, or, in other words, a No. 2 iron.

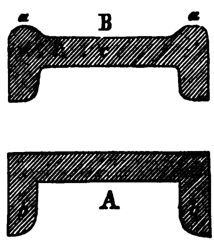
FIG. 24.

The permissible differences in draw depend, on the one hand, upon the absolute area of the section of the pass, and, on the other, upon the quality of iron. In the case of large deep passes, when the greatest reduction upon the upper, as well as upon the lower side of the bar, amounts to about 1 inch, the smallest reduction may be restricted to $\frac{2}{12}$ or $\frac{3}{12}$ of

an inch, as shown on Plate VIII., in Fig. 82, in full size passes for girders, which are used at Reschitza, and also in the passes for channel bar and girder iron, shown in Figs. 86 and 87, on the same plate. The difference between the draws or pressure upon the different parts becomes less in those passes which precede the finishing passes, while in the latter, in which it is necessary to complete the form of the flanges, these are drawn out rather more than any other part. The poorer the quality and the greater the hardness of the iron, the more nearly uniform must be the reduction of the different parts of the section.

In the case of channel bars, with very deep channels, or in the case of V iron, the rolling can be rendered very much easier if the shaping passes are so proportioned that the ridges (*a a*) are formed; in the finishing pass these ridges are much more easily pressed into the flanges or sides (*b b* in A, Fig. 25) than the superfluous iron of the middle part would be. The iron from the ridges (*a, a*) can be pressed down into the sides (*b, b*) without materially lengthening or drawing out the bar, but it would require a very heavy draw to force the iron out of the centre (*c*) into the sides. The arrangement of passes for iron of the above form, is shown in Figs. 93 and 94, on Plate IX., and the principle is susceptible of very general application in rolling shapes.

FIG. 25.



In every shape in which the iron does not lie equally on each side of the vertical centre line, as, for instance, almost all forms of tyres, rails, angle iron, with flanges of unequal width, and many other forms, the draw upon the two sides must necessarily be unequal. So, for instance, when the first T, or flanged rails were rolled at Frantschach, in Carinthia, they were rolled in the passes shown in full size by Fig. 50, on Plate IV., which were closed passes, as is usual for shapes, and for which the bars were turned 180 degrees, or half over, at each pass. The rolling itself was in this case

quite easy, and the desired form perfectly attained; but the rolls themselves were very soon worn out, because they were considerably weakened by the necessary height of the last roughing and first shaping passes, but chiefly because the draw was so unequal that the collars were pressed obliquely against each other, and were abraded to such an extent that the rolls became useless.

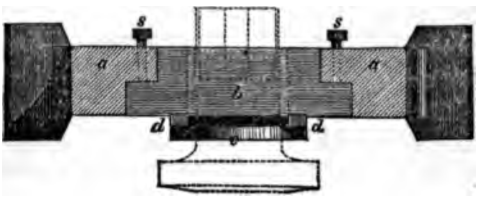
The arrangement of passes, which is now used in rolling rails, as well as shapes generally, consists in the use of one or more flatting passes, as represented, for instance, in the rail rolls shown in Figs. 44, 45, and 46, on Plate IV. In these passes the whole mass of iron is somewhat compressed, but the principal pressure comes upon the flanges, to compress and spread them out. A comparison of these passes, as shown in full size in Figs. 48 and 49, with the older forms represented in Fig. 50, show quite plainly to how great an extent the former obviate the unequal draw.

These inequalities of draw may also be obviated in some cases by another method, which is, however, less generally known and used, but which is especially useful in rolling angle iron with flanges of unequal width. It consists in so proportioning the first shaping passes, as shown in Figs. 61 and 62, on Plate V., that the narrower flange remains the thickest, so that in the finishing passes it is necessary to use a heavier draw upon this side, or, in other words, to exert more pressure upon its surface than upon that of the wider side. Thus the total pressures become nearly equal, since the pressure upon the wider flange is less, in about the same proportion that its superficial area is greater than that of the narrower flange. By this means the unequal wear of the collars is very much lessened. The unequal draw or pressure might be obviated by varying the angle of the flanges in the successive passes, so that the final angle would be the one required; but such an arrangement would entail many disadvantages, and is, so far as I know, nowhere in use.

Finally a third method, which has been long in use, consists in so arranging the journals of the rolls (which should

in this case be brasses), that they receive upon themselves the side-thrust exerted on the roll.

Fig. 26.



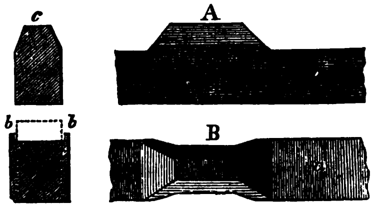
The arrangement is shown in Fig. 26, in which the roll is represented by dotted lines, and as if it had been pushed forward several inches in the direction of its axis, whereas it presses during use quite firmly against the brass, *c*. The brasses have a strong flange or collar on the roll side, between which collar and the cast-iron box two slender steel wedges are driven down vertically. The journal-box does not press against the two set screws (*s*, *s*), as usual, but is pressed directly against the chock (*a*, *a*). When the steel wedges are driven down, the brasses are drawn out of the box and pretty firmly forced against the collar of the roll. It is therefore possible, by this arrangement, to relieve the collar from the side-thrust occasioned by unequal draw, and transfer the thrust to the brasses. The latter must not, of course, be wedged too firmly against the roll, as the strength of the neck would thereby be too much taxed, and the friction greatly increased.

When it is not possible to avoid an unequal draw, the bar has a tendency, at its exit from the pass, to bend toward the side where the draw has been least. But the bar must be straight in order that the rolling may be continued; it is therefore necessary to fasten upon the bearing bar proper, blocks, called *guides*, at the exit end of the pass, so that the bar may be straightened as it passes out between them. Sometimes *guards* must be used upon the top roll to prevent the bar from bending upward.

If a very heavy draw must be applied in the finishing pass, the bar is considerably widened or spread, as in the case of an intermittent pass for spike iron, the product of which is shown in Fig. 27. When the part *a* is greatly reduced to

form the head of the spike, it is very much widened, and if the pass does not freely permit this spread, the formation of fins, as shown in section at *b*, is unavoidable, and the bar is spoiled. In order to prevent this the pass before the last must not only be of somewhat less width than the latter, but it must roll the iron in wedge form, as shown in section by *c*, with bevelled edges upon the side which is periodically compressed by the finishing pass. Seen from above, the spike rod has the form shown by *B*. The formation of fins is aided by the cold state in which the bar is rolled through the last pass, as cold iron spreads more than hot iron under the same draw. Further, cold bars wear out intermittent passes very quickly, and therefore, for this double reason, the iron must be rolled through them as hot as possible.

Fig. 27.



Passes for shapes are, as a rule, closed passes, and as this variety guides the bar pretty well by itself (*vid.* § 3, 2), other accurate guides fitted to the special form are the less necessary, since the increase of width in successive passes is inconsiderable. But this circumstance, although it renders the guidance of the bar more certain, also makes it necessary that the latter should be correctly introduced into the pass, in order that the edges of the *former*, which closes the pass, may not begin to cut as they take hold. Hence it is necessary to place suitable guides upon the bearing bar in front of the rolls, in order that the bar may be introduced straight and fairly into the pass.

One circumstance yet remains to be noticed, viz., that for all complicated passes for shapes it is very important to keep the guards sharp and in proper position, and to cool off the passes with a great deal of water, especially in the case of those in which the bar is likely to stick, and to be immediately wrapped round the roll.

§ 23. It is evident from the foregoing (under reference to § 7), that the composition, size, and form of the pile or other material, affects the shape and draw of the required passes; these elements are also essential in determining the requisite diameter of the rolls. The size of the rolls is, indeed, a question of almost as much importance as the form of their passes; if the former are small, they frequently break and suffer great wear, while if they are, on the other hand, large, they are more expensive, heavier to handle, and increase the lift to get the bar over or through (a three high mill) to the front. It will be well to consider the characteristics of each kind.

Small rolls do not require very heavy housings or fittings, are quite easily handled, contain a comparatively small weight of metal, and the bar need not be lifted very high to get it over them. They must, however, be pretty long to contain the necessary passes, while some of them are cut very deeply into the bodies; they are, therefore, comparatively weak. They require a pretty high speed of the engine, if the latter is direct-acting, or if it is not, occasion great wear and tear of gearing; while the grooves, owing to their small circumference, wear more for the same length of bar than would the grooves of a large roll, and consequently sooner require redressing. They resemble in their action a hammer with narrow dies and draw out quickly, with little spread; but the draw operates more quickly than it would between large rolls, on account of the relative shortness of the wedge-shaped space which the bar must traverse to reach the normal section of the pass. Since the bars are, therefore, as it were, less prepared for the normal draw of each pass, all the strains become more sudden than would be the case in larger rolls. A small roll limits the draw, since the latter, if too great, would break the roll, and this limitation of draw increases the number of passes, other circumstances being similar and equal; if, however, the draw remains the same, the rolls must be shorter. For instance, a case of this kind occurs to me in which the rolls of a three high mill broke down under the work for which they were designed; the housings could

neither be made stronger and larger to receive heavier rolls, nor could they be thrown aside; consequently the only alternative was to shorten the existing rolls and add one whole set to receive the passes lost by shortening the rest. Another feature of small rolls is that those passes in which the draw is at all heavy, require deep notching to insure their hold; but if these notches are pretty deep and are not very carefully considered in the formation of subsequent passes, they are apt to leave unsightly marks or laps on the finished product.

Large rolls are, of course, more expensive than small ones, require heavier housings and fittings, and give rise to greater friction. They have, however, great and manifest advantages over small ones. They are comparatively strong, since with the same length their strength increases as the square of the depth or diameter; 21-inch rolls being thus over $\frac{1}{3}$ stronger than 18-inch, while the increase of diameter is only $\frac{1}{6}$; the rods will therefore stand a heavier draw and still retain proportionately greater strength. The "nip" of large rolls is far better than that of small ones, on account of the greater surface working on the bar, and consequently greater friction; the notches may therefore be made less deep, thereby preserving the surface of the finished bar. In order to get the best effect or work from large rolls, the draw should be slightly heavier than in the small ones, which they would replace, the speed at the circumference of the respective rolls being the same. The large rolls will then do their work as quickly as small ones, while the iron is not strained so much as in the latter, by reason of the more gradual wedge-shaped approach to the normal section of the pass. In order that the circumference of a 21-inch roll might have the same speed as that of an 18-inch, the engine, if direct-acting, might run about $\frac{1}{7}$ slower, that is, about 56 revolutions instead of 65, and this decreased speed would increase the endurance of all parts of the rolls, by lessening all shocks and rendering them less sudden. For these reasons, as well as much greater certainty against unprofitable stoppage of work through the breaking down of rolls, the modern practice has been to use very heavy rolls, and this practice is already very general.

the under part of the bar (the future head of the rail) is reduced scarcely at all, while the partially formed flange is quite forcibly spread out. The less the under part of the bar is reduced, the more easily and thoroughly is the flange spread out; but in this case the iron must be very tough, or the flange is apt to crack. The last passes of the finishing rolls have the peculiarity of being "half open" passes (*vide* § 3); the sides of the head are thereby much more perfectly rounded and finished than would be the case in an open pass.

Figs. 57 and 58, on Plate V., represent the passes of the rail train of the mill at Gratz, which belongs to the "Südbahn," or Southern Railroad. In these rolls 12 passes are used, 6 of which are on one pair and 6 on the other pair of rolls. By reference to the roll drawings in Figs. 39 and 40, on Plate III., it is rendered easy to draw the rolls which belong to these passes, and which were omitted to save room (see also § 13). The flange of these rails is considerably wider than that of the former section; hence *two* flatting passes are used, viz., pass 6 in the first and pass 3 in the second pair; thus the flange is spread out more gradually to the necessary width. Pass 3 of the finishing rolls shows at a a construction the principle of which is similar to that of the similar pass of the Westphalian rolls previously mentioned, but in this case differently carried out, with the special purpose of so shaping one edge of the flange at a that it will be rolled down again in pass 4 by the former, thereby preventing the formation of a fin at a', which purpose is also perfectly accomplished in rolling.

An example of a rail train with many passes is given on Plate IV., in the Figures 44, 45, 46, the corresponding passes being represented in full size in Figs. 47, 48, and 49. This train is in use at Pravali, in Carinthia, for rolling Bessemer steel, and it rolled the first rails of that kind successfully made in that part of Austria. Between the three pairs of rolls belonging to the train 15 passes are evenly divided and d successively; but the actual number of times the ssed through the rolls is about 20, in two heats.

The reason for such a large number of passes is not at all the difficult section of rail, but lies altogether in the physical characteristics of Bessemer steel, as being comparatively hard and resistant.

The somewhat pyramidal ingots of Bessemer steel are of square section, 7 to 8 inches on a side, with rounded corners. They are principally cast of steel, containing 0.3 and 0.5 per cent. of carbon, as that containing over 0.5 per cent. would not only not be so easily rolled, but would scarcely be tough enough to stand the required deflection tests, because they would be comparatively hard and stiff. The rough ingots are heated to a full yellow heat, and are then rolled three times through the first pass, twice through the second, and twice through the third—therefore seven times through the first three passes; finally, the bar goes twice through the first shaping pass, and is then immediately returned to the furnace for the *wash-heat*, after having in the heat gone nine times through the rolls. The rolls are opened about half an inch for the first passage of the ingot, and are gradually closed again; the ingot is turned quarter over (90°) at each passage through the first three passes, but half over (180°) each time in the fourth. The second heat is higher, nearly approaching a white heat, and in this heat the ingot goes once through each of the remaining 11 passes, and is thus passed 20 times through the rolls. Out of the 11 passes used in the second heat, the second, fifth and eighth are flatting passes.

It is interesting to know that these rails were 21 feet (21.77 Eng.) long, and weighed 368 (454.33 Eng.) Viennese pounds. The ingots weighed 415 to 430 (513.35 to 530.87 Eng.) pounds in the rough. The loss in heating and rolling amounted to 4.9 per cent. Seven heats of four (4) ingots each were made in one furnace during the turn of 12 hours. The percentage of imperfect rails varied between 5 and 10 per cent.

In Figs. 39 and 44, which represent the roughing rolls of two rail trains, and Figs. 41 and 47, which represent the respective passes in full size, it will be noticed that the openings between the body-fillets are some way above the

pitch line. This is so arranged designedly, in order that fins may not be easily formed in the passes used in both cases. This method insures that any fins formed are well rolled in, as well as prevents their formation. That is, the bar is turned half over at each pass, and a fresh surface comes before the opening of the pass; the resulting fin is thoroughly rolled in at the bottom of the next pass, and in the third pass a straight surface (on which no fin has yet been formed) comes before the opening; that part of the bar on which the fin was formed in the first pass coming a good way below the parting of the third. The flaring sides of the body collars furnish additional protection against fins (*vide* end of § 30), while the surface of the bar is kept smooth and sound, because no part where a fin has once been comes again into a position where another is likely to be formed.

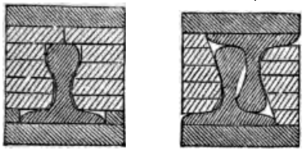
Fig. 37, on Plate III., represents a pair of rolls used in a Silesian mill for rolling mine rails; the corresponding passes are shown in full size in Fig. 38. In this pair there are 6 passes intended for successive use; the seventh is a spare or duplicate finishing pass. This pair contains only finishing passes; the roughing rolls are omitted, because they correspond exactly with the Gothic roughing rolls for bar-iron (*vide* § 11 and Figs. 5 and 6 on Plate I.), as is evident from the form of the first finishing pass. In these rolls for such a small section a flatting pass is also used, both to preserve the rolls from undue side-thrust, and to make the flange comparatively tough and soft, as discussed above in detail.

§ 25. It is necessary to work up old rails, imperfect rails or wasters, and crop ends, in the formation of the rail pile; it will therefore be useful to consider the best means of rolling them into the proper shape.

It was formerly, and is now to some extent, customary to cut the rails to the length of the pile, and to use one or two such cut pieces in the formation of the latter. These pieces, on account of their irregular form, did not fit well into an ordinary pile of puddle and rerolled bars (tops and bottoms); therefore, in order to avoid interstices between the bars and

rails, it was necessary to roll filling pieces of special form adapted to fit the rail more or less closely. The use of rail ends or pieces is now almost entirely restricted to the pile for tops and bottoms, and it has been found more advantageous to roll the pieces down singly into a flat bar. For this purpose old rails and wasters are commonly cut cold into lengths of 5 or 6 feet, reheated and rolled into flat bars twice or thrice as long as the rail pile. These bars may be made in form and size similar to puddle bars, and may be conveniently used in any desired proportion in any part of the pile.

FIG. 28.



The crop ends are usually rolled down immediately after cutting. They vary, of course, considerably in length, but may be used in the pile together with the ends cut off the puddle bars.

Fig. 53, on Plate V., shows a pair of rolls adapted to rolling crop ends, etc., into flat bars; they are in use at the Horst mill near Steele, and produce bars of 3 to 4 inches in width. The corresponding passes are shown in full size by Figs. 54, 55, and 56. The two first passes reduce the height of the rail about $\frac{3}{4}$ of an inch (drawing it out of course), but are principally useful in bending the flanges back upon the web, as shown by the dotted lines in the first pass. Between the second and third passes the rail must be turned one-quarter over, and half over for the fourth as well as for the fifth. The fifth pass turns out a flat bar, 4 inches wide by 1 inch thick. If the bar is desired 3 inches wide, it must be turned quarter over (or upon its edge) for the flatting pass No. 6, in which its width is reduced from 4 to $2\frac{1}{1}\frac{5}{6}$ inches; it is then turned again one-quarter over, and rolled through No. 7 into a bar 3 inches wide by 1 inch thick.

Those rails—which are composed of different materials in the flange, web, and head—are seldom rolled out into a bar of this kind, but are usually cut by means of slitting rolls into three parts—viz., head, web, and flange—which may then be used again in accordance with their respective qualities.

By the use of rolls so constructed as to gradually press the metal in the flange and head into the web, flat bars may be rolled from old rails and crop ends, without bending the flange at all over upon the web. This method makes a smoother bar, while it obviates the weld of the flange upon the web, and hence materially reduces the whole number of welds in the pile.

§ 26. A pair of tyre rolls used in a Silesian mill are shown in Fig. 68, on Plate VI.; they contain 6 passes, which are given in full size in Fig. 69. Figs. 70 and 71 also represent tyre rolls in use at the same mill, containing 6 passes on two pair of rolls; Figs. 72 and 73 exhibit these latter passes in full size. In one aspect it is certainly simpler and cheaper that one pair of rolls should contain the 6 shaping and finishing passes, and such is generally the case. It often happens, however, that small differences in form and size of tyres are frequently demanded, and it is then much better that the four shaping passes should be turned on one pair of rolls, which can then remain in their housings, while the small pair, with the two finishing passes, may be easily and quickly changed. In order that these small alterations of section may be readily accomplished, the last pass but one is made a flatting pass, and turned, of course, upon the short rolls; while the flatting pass in Fig. 68 is the third to be used.

By means of the flatting pass the unequal side-thrust of the rolls is somewhat diminished, as mentioned in § 22, and also especially discussed with reference to rail rolls. The chief object of their use is, however, the more perfect formation of, and a thorough work upon the flange of the tyre.

The above rolls require in use a pair of roughing rolls, with the necessary passes. These are omitted here, but their form and draw may be readily derived from the next following pair of tyre rolls.

Fig. 74, on Plate VI., represents, in full size, the welding, drawing, shaping, and finishing passes used in a Styrian mill rolling tyres. Ten passes are used, as the figure shows.

Of these, the first five, which are box passes, are on the roughing rolls; while the last five, on the other hand, are turned as closed passes upon the finishing rolls. Of the five roughing passes, the first three are to be considered as welding, and the last two as drawing passes. The bar must be turned one-quarter over before entering the 2nd, 3rd, and 5th passes respectively, but half over before entering the 4th. The third of the five finishing passes is a flatting pass.

A noteworthy difference exists between the Styrian and Silesian passes, viz., that the former tyres are finished concave on the inner side, while the latter are left straight. The object of making the inner side concave is that it may become straight after the tyre is bent into form; for if it were left straight it would be found to be rendered quite convex, which convexity, or bulge, must afterward be turned off, thereby increasing the cost of labor, and causing a greater waste of metal. Something similar occurs with reference to the other dimensions of the tyre: the inner side not only bulges out, but also becomes wider on account of the bending, while the outer side, or tread, becomes narrower. Therefore, in order that the other two sides of the tyre may remain parallel, it is necessary to roll the bar in such a manner that the inner side shall be finished narrower than the tread; while in the rolls shown in Figs. 68, 71, and 74, exactly the reverse is the case, as the inner side must be finished wider than the tread. In order to insure that the inner side be narrower than the tread, it would merely be necessary to turn the finishing pass half over, thus bringing the tread uppermost, by which means it—viz., the whole tread side or outside of the tyre—might be readily made wider as desired, being flatted out somewhat by the former of the upper roll. This method is applied in some mills, but in the majority this self-evident advantage is neglected, in order to finish the flange somewhat more accurately in the lower roll.

Tyres for disc wheels must be rolled with a rib or fillet on the inner side, to which the disc, which takes the place of spokes, may be fastened. Fig. 43, on Plate III., represents,

in full size, the shaping and finishing passes used in a Silesian mill for producing such tyres.

These examples of rolls for tyres are adduced rather to show an interesting and useful series of pass constructions than as anything at present to be recommended. Iron tyres are now seldom used, and steel tyres are almost universally weldless, and rolled in a peculiar form of mill, some of the rolls of which will be described in § 32.

§ 27. There are two circumstances to be considered in draughting passes for angle iron, viz., the equal or unequal length of the sides, and the absolute area of the section. When the sides are of equal width, angle iron is much more easily and cheaply rolled than when they are not, as in the latter case the rolls soon become worn out by the irregular side-thrust. The latter difficulty is materially diminished when the shorter side is kept thicker than the longer, as described in § 22.

If the sides of the angle iron are equal and plain, and if their edges are not required to be very smooth, a single pair of rolls may be used to produce iron varying both in width of the sides and in the thickness of the metal. The passes of such rolls must be constructed for the greatest desired width of side, as when a section with narrower sides is to be rolled, it is sufficient to give it the required size in the last pass, since it is not necessary that the iron in the sides should entirely fill out the grooves of the shaping passes. This method resembles that employed when flat bars are rolled between plain rolls, viz., rolls similar to plate-rolls. In the latter case, however, the width of the bar varies somewhat, and the corners are not sharply rectangular. The only difference between the two cases cited above is to be observed in the fact, that in rolling angle iron great care is required to introduce the centre of the angle exactly in the centre of the pass; for if the bar should deviate at all to the right or left, the width of the sides would vary considerably. In order to insure the proper introduction of the bar without accurate guides, it is only necessary to turn the passes

upside down, as it were, as shown in Fig. 65, on Plate V.; that is to say, that the former is placed on the bottom instead of the top roll. In this way it is rendered easy to introduce the angle exactly, by allowing it to rest on the former, and be carried by the same into the pass. If the groove of the pass was turned on the lower roll, the diameter would be so much decreased that it would be difficult to adopt the above method, as the bearing-plate in front of the roll would cut off a good deal of the circumference of the latter. Further comments on the use of such inverted passes will be found on page 69, in connection with the description of Fig. 60, on Plate V. In order to make the flanges thicker it is, of course, only necessary to separate the rolls as required.

It is important to consider the absolute sectional area of the finished angle iron, for when the same is small, the bar is generally worked out from a nearly square section, whereas, on the other hand, the larger sections are commonly worked out gradually from a flat bar into the required rectangular form. The first method is the simplest, but requires a greater proportional reduction of the original area than the second method, and is, therefore, not so economical or convenient for rolling large sections. Fig. 51, on Plate IV., represents the shaping of the angular section from the flat form, while Fig. 52 shows the section as drawn out of the square bar or pile. The dotted lines, *a*, *b*, *c*, *d*, in each figure represent the original section of the pile or bar, while the finished angle iron is designated by the hatched section. In each case five passes are required to finish the bar. These two sets of full size passes, representing both of the above methods, have been many years in use at Frantschach, in Carinthia.

When the angle iron is rolled up from the flat form, the length of each side may increase, while the distance between the edges remains the same, or even decreases, because the sides are gradually bent in. On this account it is not so necessary, as in the case of other forms, that one pass should be wider than the preceding; individual passes may indeed be narrower than those preceding them, as shown by the passes for angle iron with unequal sides, which are given

in Figs. 61 and 62. In order to understand how it is possible to introduce the bar into a pass narrower than the one it has just left, it is only necessary to consider that the point of the angle projects most, and is first seized by the rolls, and the new angle is formed before the greater width of the sides can become troublesome, or before the edges begin to be cut.

For the sake of simplicity and ease in turning the rolls, the deep grooves are, as a rule, all placed in the bottom roll, although this position has the disadvantage that the bar cannot, as is usually the case, be turned half over, in order to prevent the formation of fins. In order to obviate this disadvantage, more or less, the two last passes are often so constructed (*vide* Fig. 61, Plate V.), that, though really closed passes, they are yet open at the edge of the side. Sometimes, to accomplish the same object, the passes are so arranged that the bar may be turned once or twice half over; this is the case at the Donawitz mill, near Leoben; while Fig. 59, on Plate V., represents similar rolls in use at a Silesian mill.

The first formers should be roughened with a chisel, as shown in Fig. 60, in order that they may take a firmer hold of the bar.

Fig. 61, on Plate V., represents in $\frac{1}{12}$ full size a pair of finishing rolls for heavy angle iron with unequal sides. Fig. 62 gives the corresponding passes in full size. The rolls are in use at Zeltweg in Styria. The great difference between the diameters of the roll in the various grooves is worthy of remark; these differences are, in this instance, caused by the large size of the section rolled. As a rule, however, all rolls for angle iron present great differences of this kind. Further, Fig. 63 shows passes for medium heavy angle iron with equal sides; they are shown in their position on the rolls and in $\frac{1}{12}$ full size. After an examination of Fig. 61 it is easy to construct rolls for these passes, especially as the pitch line is marked on the drawings.

With reference to the roughing rolls belonging to these rolls, it is necessary to consult § 13 and Fig. 16, on

Plate II.; for an inspection of Figs. 62 and 64, on Plate V., shows at once that large sections must be rolled from correspondingly large and heavy flat bars.

Fig. 60, on Plate V., represents a pair of finishing rolls for angle iron with sides of equal width, each side being $3\frac{1}{4}$ inches wide; they are in use at Piela in Upper Silesia. There are two especially striking points to be remarked in these rolls; the first being, that all passes have the same width, viz., $4\frac{5}{8}$ inches; the second, that the iron is indeed rolled out of the flat bar; but the shaping is effected in one pass, and with nearly the full finished angle. This is a method which the moderate size of the angle iron renders practicable, but which would be, even for small sections, seldom advisable or applicable. It is, therefore, unnecessary to represent the individual passes in full size. Fig. 65 represents a set of passes for medium and small angle iron with equal sides, and which is shaped from a square or diamond through the half diamond bar. These passes are used at Neuberg in Styria, and are represented merely according to their position on the rolls and in $\frac{1}{12}$ full size, while Figs. 66 and 67 show the individual passes in full size. The inverted position of these passes, and the reasons for choosing the same, have already been the subject of remark. A notable point is the unusual height of the pitch line, as shown in Fig. 65; this somewhat excessive height was, on account of the inversion of the passes, considered necessary to prevent the bar from curling upwards. The rolls may be useful in case of necessity, but are scarcely adapted to production on a manufacturing scale.

The passes used at Seraing, in Belgium, for a peculiar variety of angle iron, are represented in Fig. 83, on Plate VIII., and the individual passes in full size, in Fig. 84. It is very doubtful whether these passes are properly constructed, and it seems improbable that the fifth pass can be correctly proportioned. The drawings were received directly from the works.

All varieties of angle iron necessitate very good material, on account of the difficulty of their manufacture and the

nature of their subsequent uses; hence, the iron generally used is that which has already been once or twice reheated and rerolled. The piles for rerolling for this purpose, are quite frequently built up of good scrap-iron.

§ 28. The passes used for T iron resemble those used for T rails. The latter are, however, in general more difficult to roll than the former, at least in the forms in which the former are applied in architectural and engineering purposes, and the difficulty of rolling the T rails becomes comparatively greater when different irons are used for the head and flange of the T rails. Therefore fewer passes are usually required for rolling T iron than for T rails.

T iron is required in much larger sizes than are the rails; which fact not only renders it difficult to proportion the passes properly, but also makes the rolling very laborious. The large size of the passes necessitates heavy rolls, especially bottom rolls, the diameter of which must often be 30 inches or more; as such heavy rolls are very expensive, it is advisable to reduce the side-thrust as much as possible by the use of flatting passes.

Figs. 75 and 76, on Plate VII., represent respectively the roughing and finishing for heavy T iron, as produced at Piela, in Upper Silesia, while the passes are appended in full size in Figs. 77 and 78. Their similarity to the passes for T rails is very striking, while the presence of 3 or even 4 flatting passes out of 10 passes in all, is equally worthy of remark. The position of the first pass is that of a flatting pass, and if this is considered as such (although this is seldom the case with the first pass), we actually find 4 flatting passes in use.

Figs. 79, 80, and 81, on Plate VIII., represent merely the passes for a medium T iron; these are constructed according to Talbot's drawings, are in full size, and the pitch line is shown. The drawings represent the two first passes in the position of flatting passes, as was the case with the above "- but the 6th pass is the only strictly flatting pass in the "here are 8 passes in all.

T or girder-iron (I beams), the top and bottom

flanges of which are similar in size and shape, is much easier to roll than simple T iron, because the metal of the former is equally divided on each side of the vertical centre line, and hence the respective side-thrusts are equal. As no flatting pass is necessary in rolling girder-iron, and as the beam is merely turned half over (180°) at each pass, the requisite passes are quite easily turned. It is, however, difficult to roll beams so large as they are sometimes demanded; the rolls must therefore be very heavy, and a reversing train should be used.

Fig. 82, on Plate VIII., represents in full size the passes for an I beam 10 inches high, as they were drawn immediately from the turning tools; these rolls are in use at Reschitza. The remarks in § 21 upon the construction of piles for I beams, as illustrated in Fig. 20, B, have special reference to these rolls, the first pass of which is a shaping pass.

It is unnecessary to adduce special examples of rolls for girder-iron, etc., of smaller sections than the above, as the corresponding passes are not only much simpler than those required by the larger sections, but are also very similar to those to be immediately described, which are required for channel-iron and heavy I beams.

§ 29. Passes for rolling channel-iron and very heavy I beams, are quite similar to the flat presses described in §§ 12 and 13 and drawn in Figs. 16 and 17, on Plate II., and so far as the roughing rolls are concerned, the respective series of passes are exactly similar. Therefore Fig. 85, on Plate VIII., represents merely that part of the finishing rolls which contains the final passes for an 8-inch channel bar, while the passes themselves are given in full size in Fig. 86. The latter figure contains the section of the bar as it comes out from the last roughing pass; this, as well as the four finishing passes, is arranged in the proper position with reference to the pitch-line. The draw and spread in the respective passes are shown distinctly in the drawing.

The section of heavy I beams is so simple, and the rolls employed in their manufacture so similar to those used for channel-iron, that it seems quite sufficient to draw, in Fig.

87, the full-size passes required for rolling the former section. As the figures show, only [illegible] roughing and finishing passes are employed instead of 4 in the case of channel-bar, although the mass of metal is greater in the former than in the latter section. The reason for employing more passes for the simpler section lies in the fact that the side-surfaces of the upper and lower grooves is quite unequal. It is evident from the respective drawings that the heavy girder beam, as well as the channel bars must be turned half over 180° after each pass. The passes of both the above are given according to Biedermann's drawings, and are in use at a Styrian mill.

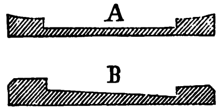
The series represented in Figs. 88, 89, and 90, on Plate IX., as used by [illegible], is somewhat unlike the above, and resembles the series for great I beams, described at the end of § 27. The first roughing passes are constructed with reference to the form of finished section, in order that the work upon all parts of the section may be as uniform as possible; the quality of the iron is thereby improved, especially in the flanges, and the strength of the beam increased. Each pass is represented in its proper position with reference to the pitch line, and their unequal division above and below this line is necessitated by turning the bar half over after each pass. The passes for I beams, represented in Fig. 82, on Plate VIII., are placed with reference to the centre line of each pass, in order that the draw of the respective passes may be clearly shown.

The five roughing passes of Fig. 88, on Plate IX., are common both to the channel bar and heavy I beam, as are also the first two finishing passes in Fig. 90. The third finishing pass in Fig. 90 completes the section of the heavy beam, while the passes drawn in Fig. 89, and marked respectively 3 and 4, are used to finish the channel bar, and the above third pass is skipped; thus the heavy beam demands one pass less than the channel bar, as was shown above in Figs. 86 and 87, on Plate VIII.

The European form of the chairs for T rails with a fish joint is somewhat similar to that of channel-iron. These chairs (*vide* § 21) are rolled in long bars, which are afterwards

sawed up to the requisite lengths. The ordinary section of the chairs is that of A in Fig. 29, although it is a frequent practice on Continental roads to use plates of the section B on heavy curves where it may seem necessary to regulate the angle of the rail to the tie. These forms are rather harder to roll than the ordinary channel iron, and therefore the requisite passes are shown in Fig. 91, on Plate IX., in their proper position in the rolls, while Fig. 92 represents them in full size.

FIG. 29.



The difficulty in rolling such forms increases with the height of the sides or lips, and it is therefore necessary to leave ridges on the back of the bar (*vide* § 22), or on the side opposite to that on which the lips are to be rolled. In order to make this method perfectly clear, Fig. 93, on Plate IX., represents the finishing and one roughing pass for the manufacture of channel bar with a deep channel ; these passes are shown in their proper position on the finishing rolls, and are appended in full size in Fig. 94. The drawings show that even the first shaping pass is turned with reference to the formation of the ridges, which latter appear more and more distinctly at each subsequent pass up to the last, during its passage through which they are forcibly pressed down into the sides of the channel bar. It is apparent that the bar, as it leaves the last roughing pass, must be turned quarter over (90°) before it enters the first shaping pass.

§ 30. Felly iron is an iron of half round form on one side, and of wedge shape on the other, and demands attention on account of its somewhat typical shape, although it is almost exclusively used in the production of wrought-iron wheels. It forms a support to the outer felly or felly proper over which the tyre is shrunk, and is welded between the spokes of the wheel, both to the outer felly and to the spokes. If the wedge-shaped side is not too sharply pointed, it is easy to develop the shape without the aid of a flatting pass, and quite simply in the ordinary way, in which the bar is turned half over at each pass. A series of such passes is repre-

sented in Fig. 95, on Plate IX., and Fig. 96 shows the individual passes in full size with reference to their draw and irrespective of their position in the rolls, which is distinctly given in Fig. 95.

If, on the contrary, the wedge-shaped side is very sharp and thin, it is necessary to introduce a flatting pass, as in Fig. 97, which represents in $\frac{1}{12}$ full size, a set of rolls of a Silesian mill; the respective passes are given in full size in Fig. 98. In this case the flatting pass is placed in the middle, and is only to be recognized by its position with reference to the rest, as it could not be recognized as such if considered singly.

It is easy to construct rolls for fish plates, as the form of the latter is usually quite simple. Fig. 99, on Plate X., represents a pair of rolls for a very simple variety, while the full-size passes are appended in Fig. 100. The shape of the former of the second pass is rendered somewhat unusual by the necessity of preventing fins from forming at the sharp corners shown in the third pass, in which latter, however, the draw and consequent tendency to form fins is very much less than in the former pass. The sharp corners of a former are avoided in the finishing pass, by giving this latter the form of an open pass, but placing this open pass in the position of a closed one and letting the *former* work between two collars, as in the case of a closed pass. This union of the open with the closed pass has been already noticed several times, and is often exceedingly useful. The immediate outlines of such a pass are those of an open one (*i. e.*, there is a groove in the *former*, so that in reality the *former* acts the part of the top roll of any set with open passes), but considered in its general relations and position, the pass must be denominated a closed one.

§ 31. As an example of a very useful class of passes, it will be well to consider those which are used in rolling rods of peculiar form, intended to be cut up into spikes. In this country we use the spike machine almost exclusively, but it is
a probable that we might find passes of a form similar to
y useful for rolling a variety of other shapes which

require periodical projections. The form of the subjoined passes for spike rod is such that the notches correspond to the heads of the single spikes. In order to fill out the notch properly with the metal which is forced up into it, a very heavy draw is required, and if the pass is narrow, fins are very likely to be formed. In § 22, however, a method of avoiding the latter was described, which is in use at Mayr's mill near Leoben.

At Reschitza the rods are finished in another way. Fig. 101, on Plate X., gives in $\frac{1}{4}$ full size a front elevation and a section of the rolls used in this mill. The circumference of the rolls is equal to four times the length of a single spike, and at every revolution the corresponding four notches form the head of a single spike. The rod leaves the roughing rolls with a rectangular section, $\frac{1}{2}$ an inch thick by $\frac{11}{12}$ of an inch wide, which dimensions remain unchanged in the head of the spike.

In the finishing rolls five similar passes, *a*, *a*, and a very wide pass, *b*, are used. Only one of the former (*a*) is used at a time, but five are on the rolls, because the corners of the holes of the dies for the spike head are soon worn out of shape even though the pass is an open one. On account of the open form of the pass, the fins formed will be in the middle of the side, and are made very blunt by rounding off the corners a good deal. The drawing represents three passes with a width of $\frac{1}{2}$ an inch, which is also the thickness of the rod as it reaches them; they might be wider in order to facilitate the introduction of the rod, but the extremely rounded form of the collars renders such extra width unnecessary. In order to remove the fins from the shaped rod, it is rolled through the wide flat pass, *b*, the height of which is equal to the thickness of the spike rod, *i. e.*, $\frac{1}{2}$ an inch.

Fig. 102 represents in *A* a single spike as cut off of the rolled rod, while *B* represents the form into which it is brought by hand, and in which it is sold. The spikes might be more readily and very quickly finished by a machine constructed for the purpose.

In order to show how the same form may be attained by very different means, a third method is subjoined, which was

in use at Fridau's mill, near Leoben. Fig. 103, on Plate X., gives the front size of the rods in ¼ full size, and it will be observed that the section is dotted in order to save space. The rolls contain 3 first and 3 second shaping passes which are turned as closed passes, and the differences between them are very small, as they are not intended to be used successively upon the same rod; so many passes are necessary to ascertain those which shall be used, according to the heat and quality of the metal in the rod, in order to obtain the best results. Only one, or at most two, of each set of shaping passes is used, while the height of the passes is often slightly changed by raising or lowering the upper roll.

The rolls contain only one intermittent pass, if it may be called pass; this one, however, is 15 inches long, and forms the end of the body of the roll. Only a small part of the whole width is used at a time, viz., so much as the rod takes up; the latter is kept in position by an accurate guide fitted to and projecting between the rolls (similar to that drawn in Fig. 34, on Plate III., and described in § 13). As one part becomes worn, the guide may be moved further along the rod, thus rendering the pass serviceable for a much longer time. This peculiar form has the additional advantage that the notches may be quickly and easily formed in a planing machine, whereas the notches in a narrow pass must be finished with great difficulty by hand.

After the head has been pressed up in this intermittent pass, or intermittent portion of the roll, it is turned quarter round, *i. e.*, upon its side, and passed through a pair of small polishing-rolls, in which any fins are rolled down, and the with of the bar between the heads is reduced by the amount to which it spread in the intermittent pass.

Fig. 104 represents in *A* the rough spike as cut from the rod, and in *B* the spike as finished by hand. A very simple method of avoiding fins, though one which is little known and seldom used, is shown in the shaping passes of these [illegible] 103). The sides of the collars are flared out in-
[illegible]traight, and the bar is turned half over
[illegible] bringing the narrow bottom of the bar

into the wide top of the next pass, which top is so much wider than the bar that scarcely any draw will force the metal out into fins. This method is very efficacious, and deserves universal application in rolling flat and square bar or hoop iron, as it leaves the corners perfectly free from fins.

§ 32. The method pursued in turning passes for a variety of small shapes is illustrated by Figs. 105, 106 and 107, on Plate X., which represent four different series of passes for sash iron, constructed according to drawings from Seraing. The passes are drawn in full size and in their proper position on the rolls, but the rolls themselves are not represented further than is necessary to render their completion easy. The radii (half diameter) of the rolls are, therefore, given in figures on the end collars.

In order to avoid the formation of fins, all the sharp corners and edges are rounded off, and the passes are so placed that the bar must be turned each time half over (180°). They are also so proportioned as to allow for a small spread, so that the bar may enter the pass easily. It would also be well to flare the side of the passes somewhat, as in Fig. 103, particularly if the stock rolled was red short, or of low quality.

As the roughing rolls for these shapes contain only Gothic and flat passes, it is merely necessary to refer to previous examples of similar rolls.

In rolling such small shapes, it is very necessary to use guides which are closely fitted to the rolls and to the pass, in order to prevent the destruction of or cutting off the corners of the bar as the grooves take hold. The diameter of the top roll in the grooves is throughout comparatively great, as the drawings show, in order that the bar may have a strong downward tendency, while accurate guards are used and water is plentifully applied. These precautions are necessary to prevent the bar from curling round the roll.

§ 33. Hitherto our attention has been confined to the more usual varieties of passes, but the definition of the term pass,

given in § 2, would require that many other and quite different arrangements for rolling iron should be discussed. To treat the subject fully, however, would be almost impossible in a work of this character, especially as the number of drawings would be largely increased. It will, therefore, be sufficient to describe the principal varieties of machines for rolling or slitting iron, which cannot be strictly classed as rolls with passes.

The Slitting Mill is a very important and very generally used machine for slitting or dividing, at a single pass, flat bars or sheet-iron into a number of rods, as nail rods or sheet for welded boiler tubes. Generally 10 or more of the smaller rods are slit off at a time, with the length and thickness of the original bar or sheet, but with a width which is regulated by the distance between the cutting discs. These discs operate exactly as circular shears, but many of them are united, as it were, in one piece, the middle discs cutting on both edges. The discs are forged singly, either wholly of cast-steel or of iron, to which steel is welded, to form the edge. Between two of these discs is placed another of the same or any desired thickness, but less diameter, and the whole are fixed concentrically upon an iron spindle, which is provided with the necessary neck and pods. These discs and short cylinders may be fastened by being driven up by screws, or a short, heavy cotter or wedge against a fixed collar at the other end of the spindle. When, however, the width of the desired slit sheet is considerable, it is customary to use cast-iron rolls, upon which collars are cast of the necessary diameter, and at such distances that when faced on the circumference with rings of steel, they will allow the steel rings on the collars of the top and bottom rolls to work close up to each other, thus making the slit. The collars are ordinarily faced with semicircular rings, fitted on to a turned face on the collar, and fastened with counter-sunk bolts. These mills must be very accurately constructed, and require a good deal of attention in use, but do their work very quickly. They are generally placed at the finishing end the train, that the sheet or bar may be slit immediately g the polishing rolls or the last pass.

The so-called "collar rolls" are used to widen out any individual part of a flat bar which is intended to be bored for a bolt. These bars are generally those used for forming the links of solid chain suspension bridges, and often require to be widened at each end as well as in the middle. In order to be able to roll at will such wider parts, the collar rolls are generally constructed of a wrought-iron spindle, upon which, at the required intervals, wrought-iron collars are shrunk. These collars may be readily moved by being heated by a thick iron ring, laid around them in segments at a white heat; the consequent expansion loosens their hold on the spindle, and they may be moved as desired. The spindle may, of course, be made of cast-iron, and where a demand for special forms exists, the necessary collars may be cast solid with the spindle. In the practice of Howard, Ravenhill & Co., of Rotherhithe, the spindles are wrought-iron, 7 to 8 feet long, and turned to a diameter of 6 to 7 inches. They are, of course, furnished with necks and pods, which are included in the above length. The wrought-iron collars are shrunk on the cylindrical body of the spindle, and are not rectangular, but have a rounded or convex surface, in order that there may be no abrupt depression in the bar. In rolling, the bar is passed three or four times through the rolls, while at each passage the top roll is lowered. The collar roll housings are placed at the end of the train in which the bars are rolled, in order that the latter may be finished at a single heat. If arranged to reverse, they are placed at right angles to the end of the train, and driven from the respective rolls by an arrangement of cone pinions, constructed to throw in and out of gear at will, and thus reverse as desired.

The term "end rolls," or "overhang rolls," may be applied to those rolls which are merely spindles between the necks, and whose body is merely a short continuation of the spindle beyond one neck, while the other end of the spindle is connected with the engine by means of gearing. The short body or head of the roll contains only one pass, that is, the *former* is turned upon the upper head and the *groove* into the lower one, or the groove on the stationary and the former

upon the movable, when the spindles are arranged as in an ordinary tyre mill.

The reason why such an arrangement is necessary is because these end rolls are required for rolling tyres, etc., the form of which objects is a closed ring, which must be placed in position and removed quite easily; one side of the pass must, therefore, be left entirely open, or at least be easily opened by moving back the movable spindle. The draw of these passes or rolls is given by continually moving the rolls together, or the movable against the stationary head, while the tyre, or other object, is being rolled. As a very considerable force is required to move the rolls together, the movement cannot be accomplished by hand, and it is necessary to employ an arrangement with friction pulleys, by which the rolls may themselves work the shifting screw or screws, or a small steam-engine, or better, a hydraulic press, to raise the journals of the bottom roll, or press the movable one up.

As the tyre is rolled out its diameter becomes greater, and the cross-sectional area of the metal becomes proportionately smaller, as well as the difference between the external and internal diameters. The speed of the rolls must, however, vary between themselves and become more nearly equal as the difference between the diameters grows less, in order to avoid an irregular draw and even cutting away of the metal; hence the end rolls are often provided with from 2 to 4 passes, the relations of the diameters of the grooves of which are different. The diameters of the grooves are so arranged that they may at first draw the outside or tread the most, and that each succeeding pass may draw the same more nearly equally with the inner surface. Another arrangement consists in using two separate pairs of end rolls driven by the same motor, and with similar relations of draw. The latter method has the advantage of finishing and centring the tyre at the same time.

The axes of the spindles may be either *horizontal* or *vertical*. The horizontal spindles are in use at Blaenavon and Rotherham, in England, and Seraing, in Belgium, as well as

in several French mills, and at Stefanau, in Moravia. In the vertical arrangement, one roll is fixed in position and merely rotated, while the other, in addition to its rotary movement, is also moved toward the former; the latter roll is generally the inside one, *i. e.*, that which forms the inner surface of the tyre. This arrangement, with two passes on the rolls, is in use at Monkbridge, in England, while a similar machine at Bochum has three or four passes on its rolls. In changing from one pass to another, the rolls must of course be opened wide and the tyre lifted into position.

The "Universal Mill" has been already mentioned (§ 12) as the best means of saving a great variety of simple flat passes and consequent stock of rolls. It has been described in many technical journals, but especially well by the inventor himself in "*Dingler's Polytechnisches Journal*," vol. 164, pp. 401–403. The inventor of this arrangement of rolls is Daelen, of the Horde mill (*vide* § 12). Mr. Wagner, of Maria Zell, has made some useful improvements upon the original, and built quite a large mill of this kind. The mill itself consists of two horizontal rolls which can be closed and opened, and immediately in front of them two vertical rolls to act upon the edges of the bar. The various improvements consist chiefly in the mode of applying and regulating the gearing which moves the respective rolls.

This mill is not well adapted for rolling very thin iron, because such bars or rods become quite cold in the last few passes, and are thus proportionately more spread (§ 7) sidewise; which spread the vertical rolls cannot reduce by any means so easily as they could at first, when the heat was high and the spread inconsiderable. If the bar were thin and the spread considerable, it would be almost impossible to prevent it from being bent (in the direction of its width) between the vertical rolls.

The rolls used for tubes with thin walls and large diameter, have the peculiarity that the pass is divided upon four rolls, which are of segmental form, and the surfaces of which form 90° of a circle, corresponding to that of the outside of the tube, while a mandrel carried on a long stem forms the

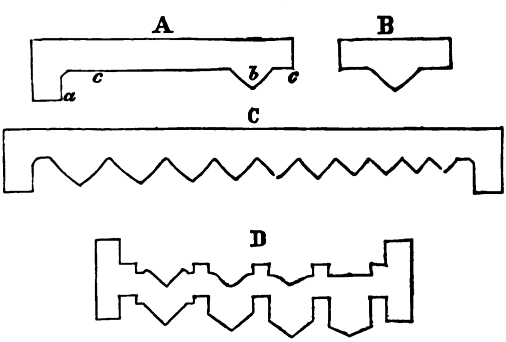
inner circular surface. If the draw were heavy and the walls of the tube thin, it would be impossible for two ordinary geared rolls (the passes of which have a varying surface speed) to bring the tube over the mandrel; this is, however, easily accomplished by the four rolls geared so together that their surface speed is quite equal. Each of the four segmental rolls contains, as above, one quarter of the required circle, two being placed horizontally and two vertically.

§ 34. The manner in which rolls are turned up in the lathe may be succinctly described as follows:

The requisite form must, of course, be laid out on paper in detail and in full size. Templates are then formed in sheet iron, or brass, exactly according to the drawing, and the necessary tools are also, for the most part, shaped to correspond with the various parts of the drawing. New tools, however, are only needed for those parts which are not usual, such as the bottoms of grooves and faces of formers; for rounding off the corners of the body-fillet, etc., and for forming many other parts, no special tools are necessary, as the forms of such parts are those which often occur in all rolls.

The templates may be prepared either for each pass singly, or one general template may be cut out for the whole body of the roll, *i. e.*, all grooves, formers, collars, or body fillets which may occur thereon. In Fig. 30, A and B represent templates for single passes, while C includes the whole body of the roll. Templates are used to give the exact form of a pass, as well as its proper

FIG. 30.



position on the rolls; therefore, a template of the form B is obviously insufficient, and is accordingly used merely for convenience, so as to avoid frequent handling of such a large plate as C. The form of template shown in A is used to determine the exact position of any given groove, the part *a* being pressed against the outside of the end-fillet, and the parts *c c* lying on the body-fillets or collars, as the case may be; as this form necessitates a number of unwieldy templates, the form C should be used in preference. One template suffices for both rolls, if the passes used are open and equally divided at the pitch line, since the small differences of the diameters of the respective grooves in each roll are without influence on their form. It is, on the contrary, necessary to employ two templates, or to utilize both sides of the same one, as in D, Fig. 30, if the passes are of the closed form, as these are scarcely ever divided equally at the pitch line.

The roll, as it comes from the sand, is placed between the centres of a lathe, and the sinking head or riser cut off; it must then be accurately centred and the necks turned up roughly, to ascertain whether or not any fault or flaw exists, which would be sufficient to condemn the roll; if there is none, the necks are finished. It is most convenient to rough out and finish the necks on a lathe with feed, and then to transfer the roll into the regular steady rest to rough out and finish the passes. In order to turn up the passes, it is necessary to support the roll on its necks, and so firmly that it will not be sensibly jarred by the tool, which presses with considerable force against it. The necks are, therefore, supported in "steady rests," constructed somewhat similarly to the housings in the train, that the roll may be supported against thrust in any direction.

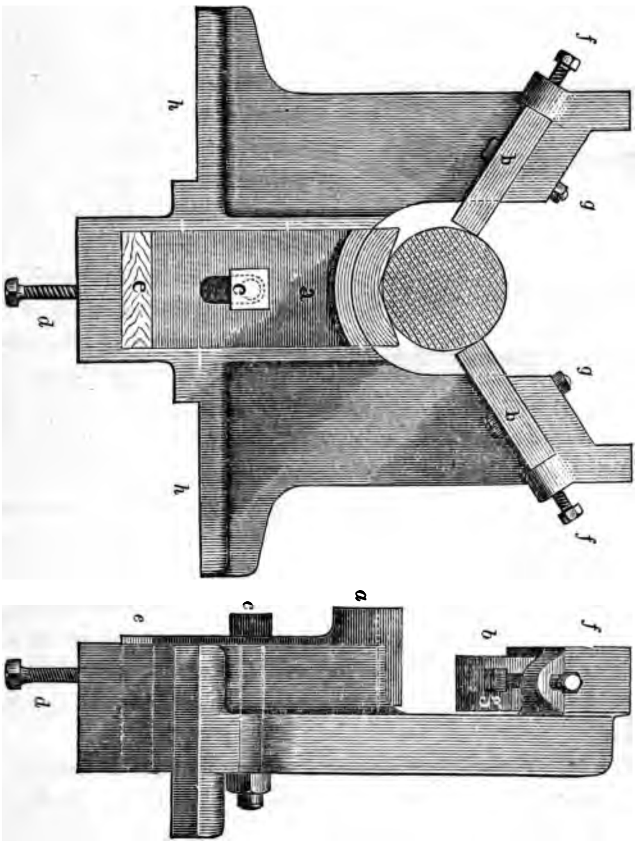
The steady rest shown in Fig. 108, on Plate VII., is well adapted for turning small rolls, on account of the firmness with which the roll can be held in position; the form is antiquated, however, and it is introduced as an illustrative type of its class rather than as an example for practice. The base *a* rests on the bed of the lathe, and is fixed in position by the cross-piece *c*, which is drawn firmly up against the under

side of the bed by means of the screw *b*. The top is left open, and is closed when necessary by the bar *d*, which is held down, and in place, by the screws *e e*. The inner sides of the uprights are quite smooth, and the edges rectangular, and the side chocks are constructed to overlap them somewhat on the inner side. The top and bottom chocks *h h* are let into the bars *i i*, which are here represented as wood, but which it is better to make hollow and of iron. If the roll is small, it is well to leave it still between the lathe centres, although supported in the steady rest, in order that the roll may be immovable endwise; if large, however, it is driven either by a sleeve, or by a casting resembling half a sleeve, which is bolted on the face plate, while any movement endwise is prevented by the portion of the end-fillets against the chocks. The screws *k k* at the sides, *m* at the top, and the slender wedge *l* at the bottom, set up the chocks to their exact position.

One of the simplest and most practical forms of "steady rest" or "housing" for all kinds of rolls is that shown in Fig. 31. Here there is an U-formed standard, from the bottom of which a strong flange projects on each side; the lower face (*h*) of this flange is planed smooth and rests on the bed of the lathe, being usually held in position with bolts, so arranged in various ways as to be easily shifted. At the junction of the sides of the standards there is a groove, in which the piece *a* moves up and down, being held in position by the bolt *c* and block of wood *e*, and being moved by the set screw *d*. This piece (*a*) supports the neck of the roll. At the top of each of the sides of the standards there is an overhanging lug, the inside of which projects downwards lower than the outside. Through this lug the bolt *g* projects and works in a slot in the piece *b*, which it can firmly hold in any required position, when the piece *b* has been moved into that position by means of the set screw *f*. All the surfaces of *b* and the lug which come in contact with each other are, of couse, carefully finished. These pieces *b* project downwards against the neck of the roll, thereby preventing it from springing upwards, though not opposing its rotary ·ion. The pieces *b* are called "jaws," and in order

that they may be in the same vertical plane as the rest *a*, the upper part of the latter projects so as to come under them. If the axis of the roll, on being placed on the steady rest, does not coincide with a line drawn between the centres of the lathe, the rest *a* may be raised till the roll is in the proper position.

FIG. 31.



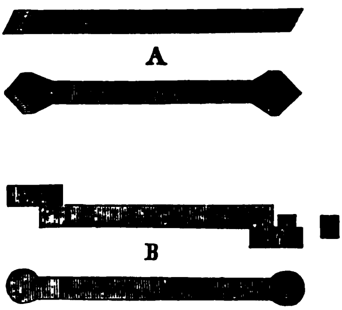
Scale ¾ in. = 1 foot.

Tools of hard-chilled iron are sometimes useful for the first rough cuts, to remove the hard skin; but these are seldom used, and it is better to make all of good cast-steel. For small work, both ends of the tool are arranged to cut as

shown in Fig. 32, A; for heavy work, however, such a form is not advisable, as the tool must in one form of rest be blocked firmly into, and placed and forced against, the roll by a powerful screw, acting on the flat end of the tool, and in another form of rest be shaped like an ordinary lathe tool.

It is advisable to weld a plate of cast-steel (as the cutting edge) upon an iron tool, as the exclusive use of steel, except in the case of smaller tools, would be quite expensive.

Fig. 32.



It is sometimes advisable that the cutting piece should be merely inserted in the tool, and not welded upon it. For example, as the passes for light round iron must be turned exactly circular (§ 16 and § 18), it is best to prepare in the lathe a cylinder of steel of the exact diameter of the required circle; then cut the same up into small cylinders; plane the ends and harden the pieces. These hardened cylinders are let in for about half their length into the end of the tool which has been formed for their reception, as shown in B, Fig. 32. Those oval passes, which partially consist of two similar arcs, may also be best turned in this way, by merely cutting in to the necessary depth. The cylinder may be turned round as its edge becomes worn, and the edges of the other end may be subsequently used. When the edges of both ends are worn out, they merely require grinding to restore them to the proper shape.

The large roughing passes are usually cast in the roll quite near the finished size and form, and it might probably be well to leave the largest grooves untouched, as they do not require any very great accuracy, would soon be worn smooth, and the hard skin would greatly improve their wear.

If passes of large size must be turned wholly out of the body of the roll, it is well to use at first a simple tool, which may be easily made and repaired, and to finish with the

special tools, which are prepared with considerable difficulty.

In turning closed passes, the formers of which must fit with as little play as possible into their respective grooves, it is well to use a template for the whole body of the roll. When the rolls are finished it is well to place one over the other, the latter remaining in the steady rest, just as it was turned. To facilitate this, the sides of the rests may be made high enough to take in the roll, and carry it as in an ordinary housing, or any special carrying arrangement may be placed over the steady rest. This comparison of the rolls facilitates the discovery of any mistakes in turning, and gives an opportunity to remedy faults, or improve the form, as the case may be. We have already seen that the sides of the grooves of closed passes are not exactly perpendicular, but flare outwards to the extent of $\frac{1}{48}$ to $\frac{1}{24}$ of an inch or more, that all sharp corners and angles of the groove and former must be avoided as far as possible, and that it frequently happens that it is necessary to alter a set of rolls according to the results of their first trial in the train, as these are sometimes unsatisfactory.

TECHNICAL TERMS

USED IN

ROLL-TURNING,

IN

ENGLISH, GERMAN, AND FRENCH.

ENGLISH.	GERMAN.	FRENCH.
Apron, *vid.* Bearing bar.		
Bearing bar.	Walzenbank.	Tablier, or *before the rolls*, Plague des guides. Tablier, or *behind the rolls*, Plague des gardes.
Body-fillet.	Walzenring.	Cordon.
Box or Sleeve.	Kuppelungs Muffe, or simply Muffe.	Manchon d' accouplement.
Box groove.	Flach Kaliber (one variety of).	Cannelure rectangulaire.
Brasses, *vid.* Journal-box.		
Breaking box.	Brechkapsel, Brechbock.	
Breaking shaft, *vid.* Spindle.		
Chilled rolls.	Hartwalzen.	Cylinders coulés en coquilles.
Chock.	Lager, Zapfenlager.	*Above all necks*, Chapeau de cage. Between or below the necks, Tourillets.
Clutch.	Keilmuff, Kuppelungsscheiben.	Èchappement, manchon à griffes.
Collar.	Walzenring-ring, Rippe.	Collet.
Coupling crab, *vid.* clutch.		
Diamond pass.	Quadrat kaliber.	Cannelure carrées.
Draw or Draught.	Abnahmsverhältniss.	Tirage (Pression).
Edge pass.	Stauch kaliber.	
End-fillets.	Endring.	Cordon.
Feed plate, *vid.* Bearing bar.		
Fillet.	Walzenring.	Cordon. (Cordon des cylinders femelles.)
Finishing pass.	Vollend kaliber.	Cannelure finisseuse.
Finishing rolls.	Vollend walzen, or Schlicht walzen.	Cylinders finisseures.
Fin.	Bart.	Gerçure.
Flat pass.	Flach kaliber.	Cannelure plate.
Flatting pass.	Breitungs kaliber.	Cannelure de champ.

ROLL-TURNING—Continued.

ENGLISH.	GERMAN.	FRENCH.
Former.	Patrize, Kaliberring.	Rondelle, or Cordon des cylinders mâles.
Gothic pass.	Spitzbogenkaliber.	Cannelure ogive.
Groove.	Einschnitt, Matrize.	Cannelure.
Groove and Former.	Matrize and Patrize.	Cannelure and Rondelle, or Cannelure des cylinders femelles, Cordon des cylinders mâles.
Guards.	Abstreifmeisel.	Gards, Racloirs.
Guides.	Einlässe.	Guides or Gides.
Guide rolls.	Feineisenwalzen.	Gid rolls.
Housing (train).	Walzen gerüststander, or simply Ständer.	Cage.
Housing (lathe), *vid.* Steady rest.		
Journal-box.	Einsetzlager.	Coussinet.
Merchant rolls.	Grobeisenwalzen, or Feineisenwalzen, or Façoneisenwalzen.	Cylinders marchands.
Mill bars.	Rohscheinen.	Fer ébauché.
Neck.	Lagerzapfen or Laufzapfen.	Tourillon.
Oval pass.	Ovalkaliber.	Cannelure elliptique, or Cannelure plateuse.
Pass.	Kaliber.	Cannelure.
Pitch line.	Mittellinie.	
Plate rolls.	Blechwalzen.	Cylinders à tôle.
Pod.	Kuppelungszapfen.	Bout or Trèfle.
Puddle rolls.	Luppenwalzen.	Cylinder ébaucheurs.
Reduction, *vid.* Draw.		
Roughing pass.	Vorkaliber, or Streckkaliber.	Cannelure dégroisisseuse
Roughing rolls.	Vorwalzen, or Streckwalzen.	Cylinders dégroisisseurs.
Shoe (train).	Sohlplatte.	Lit.
Sleeve, *vid.* Box.		
Spindle.	Zwischenwelle.	Allonge.
Standard, *vid.* Housings.		
Step rolls.	Stufenwalzen, Staffelwalzen.	
Steady rest (lathe).	Lunette.	Poupée a lunette.
Table, *vid.* Bearing bar.		
Train.	Walzenlinie.	Jeu.
Tyre rolls.	Tyreswalzen.	Cylinders à bandages de chemin de fer.

TABLE

SHOWING IN ENGLISH INCHES THE EQUIVALENTS OF AUSTRIAN INCHES AND PARTS OF INCHES.

Austrian.		English.	Austrian.		English.	Austrian.		English.
1′	=	1′ 0.445″	4′	=	4′ 1.782″	7′	=	7′ 3.118″
2′	=	2′ 0.891″	5′	=	5′ 2.227″	8′	=	8′ 3.564″
3′	=	3′ 1.336″	6′	=	6′ 2.673″	9′	=	9′ 4.010″

Austrian Inches in twelfths.	English Inches in decimals.	Austrian Inches in twelfths.	English Inches in decimals.
0 $\frac{1}{12}$″	0.0864275″	2″ $\frac{4}{12}$″	2.419″
$\frac{2}{12}$″	.172″	$\frac{5}{12}$″	.506″
$\frac{3}{12}$″	.259″	$\frac{6}{12}$″	.592″
$\frac{4}{12}$″	.345″	$\frac{7}{12}$″	.679″
$\frac{5}{12}$″	.432″	$\frac{8}{12}$″	.765″
$\frac{6}{12}$″	.518″	$\frac{9}{12}$″	.852″
$\frac{7}{12}$″	.604″	$\frac{10}{12}$″	.938″
$\frac{8}{12}$″	.691″	$\frac{11}{12}$″	3.024″
$\frac{9}{12}$″	.777″	3″	.111″
$\frac{10}{12}$″	.864″	$\frac{1}{12}$″	.197″
$\frac{11}{12}$″	.950″	$\frac{2}{12}$″	.284″
1″	1.037″	$\frac{3}{12}$″	.370″
$\frac{1}{12}$″	.123″	$\frac{4}{12}$″	.457″
$\frac{2}{12}$″	.209″	$\frac{5}{12}$″	.543″
$\frac{3}{12}$″	.296″	$\frac{6}{12}$″	.629″
$\frac{4}{12}$″	.382″	$\frac{7}{12}$″	.716″
$\frac{5}{12}$″	.469″	$\frac{8}{12}$″	.802″
$\frac{6}{12}$″	.555″	$\frac{9}{12}$″	.889″
$\frac{7}{12}$″	.642″	$\frac{10}{12}$″	.975″
$\frac{8}{12}$″	.728″	$\frac{11}{12}$″	4.062″
$\frac{9}{12}$″	.814″	4″	.148″
$\frac{10}{12}$″	.901″	$\frac{1}{12}$″	.234″
$\frac{11}{12}$″	.987″	$\frac{2}{12}$″	.321″
2″	2.074″	$\frac{3}{12}$″	.407″
$\frac{1}{12}$″	.160″	$\frac{4}{12}$″	.494″
$\frac{2}{12}$″	.247″	$\frac{5}{12}$″	.580″
$\frac{3}{12}$″	.333″	$\frac{6}{12}$″	.667″

TABLE OF AUSTRIAN AND ENGLISH INCHES—*Continued.*

Austrian.		English.	Austrian.		English.	Austrian.		English.
1′	=	1′ 0.445″	4′	=	4′ 1.782″	7′	=	7′ 3.118″
2′	=	2′ 0.891″	5′	=	5′ 2.227″	8′	=	8′ 3.564″
3′	=	3′ 1.336″	6′	=	6′ 2.673″	9′	=	9′ 4.010″

Austrian Inches in Twelfths.	English Inches in Decimals.	Austrian Inches in Twelfths.	English Inches in Decimals.
4″ $\frac{7}{12}$″	4.753″	7″ $\frac{6}{12}$	7.778″
$\frac{8}{12}$″	.839	$\frac{7}{12}$	.864
$\frac{9}{12}$″	.926	$\frac{8}{12}$	.951
$\frac{10}{12}$	5.012″	$\frac{9}{12}$	8.037″
$\frac{11}{12}$	.079	$\frac{10}{12}$	.124
5″	.185	$\frac{11}{12}$	.210
$\frac{1}{12}$	.272	8″	.297
$\frac{2}{12}$	.358	$\frac{1}{12}$	.383
$\frac{3}{12}$	.444	$\frac{2}{12}$	.469
$\frac{4}{12}$	.531	$\frac{3}{12}$	.556
$\frac{5}{12}$	.617	$\frac{4}{12}$	.642
$\frac{6}{12}$	.704	$\frac{5}{12}$	.729
$\frac{7}{12}$	.790	$\frac{6}{12}$	.815
$\frac{8}{12}$	.877	$\frac{7}{12}$	.902
$\frac{9}{12}$	.963	$\frac{8}{12}$	.988
$\frac{10}{12}$	6.049″	$\frac{9}{12}$	9.074″
$\frac{11}{12}$	.136	$\frac{10}{12}$	.161
6″	.222	$\frac{11}{12}$	.247
$\frac{1}{12}$	.309	9″	.334
$\frac{2}{12}$	.395	$\frac{1}{12}$	.420
$\frac{3}{12}$	.482	$\frac{2}{12}$	.507
$\frac{4}{12}$	.568	$\frac{3}{12}$	.593
$\frac{5}{12}$	.654	$\frac{4}{12}$	.679
$\frac{6}{12}$	.741	$\frac{5}{12}$	.766
$\frac{7}{12}$	.827	$\frac{6}{12}$	.852
$\frac{8}{12}$	.914	$\frac{7}{12}$	.939
$\frac{9}{12}$	7.000″	$\frac{8}{12}$	10.025″
$\frac{10}{12}$	.087	$\frac{9}{12}$	.112
$\frac{11}{12}$	.173	$\frac{10}{12}$	.198
7″	.259	$\frac{11}{12}$	.284
$\frac{1}{12}$	.346	10″	.371
$\frac{2}{12}$	.432	$\frac{1}{12}$	.457
$\frac{3}{12}$	.519	$\frac{2}{12}$	.544
$\frac{4}{12}$	.605	$\frac{3}{12}$	.630
$\frac{5}{12}$	.692	$\frac{4}{12}$	.717

TABLE OF AUSTRIAN AND ENGLISH INCHES—*Continued.*

Austrian.	English.	Austrian.	English.	Austrian.	English.
1′ =	1′ 0.445″	4′ =	4′ 1.782″	7′ =	7′ 3.118″
2′ =	2′ 0.891″	5′ =	5′ 2.227″	8′ =	8′ 3.564″
3′ =	3′ 1.336″	6′ =	6′ 2.673″	9′ =	9′ 4.010″

Austrian Inches in twelfths.	English Inches in decimals.	Austrian Inches in twelfths.	English Inches in decimals.
10″ $\frac{5}{12}$	10.803″	11″ $\frac{3}{12}$	11.667″
$\frac{6}{12}$	.889	$\frac{4}{12}$	.754
$\frac{7}{12}$	.976	$\frac{5}{12}$	.840
$\frac{8}{12}$	11.062″	$\frac{6}{12}$	.926
$\frac{9}{12}$	.149	$\frac{7}{12}$	12.013″
$\frac{10}{12}$	.235	$\frac{8}{12}$	.099
$\frac{11}{12}$	.322	$\frac{9}{12}$	.186
11″	.408	$\frac{10}{12}$	.272
$\frac{1}{12}$	.494	$\frac{11}{12}$	.359
$\frac{2}{12}$	.581	12″	12.44556″

English Inch in decimals.	English Inch in thirty-seconds.	English Inch in decimals.	English Inch in thirty-seconds.
.031	$\frac{1}{32}$	.531	$\frac{17}{32}$
.062	$\frac{1}{16}$	.562	$\frac{9}{16}$
.093	$\frac{3}{32}$	.593	$\frac{19}{32}$
.125	$\frac{1}{8}$	.625	$\frac{5}{8}$
.156	$\frac{5}{32}$	.656	$\frac{21}{32}$
.187	$\frac{3}{16}$	.687	$\frac{11}{16}$
.218	$\frac{7}{32}$	.718	$\frac{23}{32}$
.250	$\frac{1}{4}$	.750	$\frac{3}{4}$
.281	$\frac{9}{32}$	.781	$\frac{25}{32}$
.312	$\frac{5}{16}$	.812	$\frac{13}{16}$
.343	$\frac{11}{32}$	.843	$\frac{27}{32}$
.375	$\frac{3}{8}$	.875	$\frac{7}{8}$
.406	$\frac{13}{32}$	.906	$\frac{29}{32}$
.437	$\frac{7}{16}$	.937	$\frac{15}{16}$
.468	$\frac{15}{32}$	.968	$\frac{31}{32}$
.500	$\frac{1}{2}$		

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